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② Northern Gulf of Mexico Continental Slope Study Annual Report Year 3

④a Volume II: Technical Report

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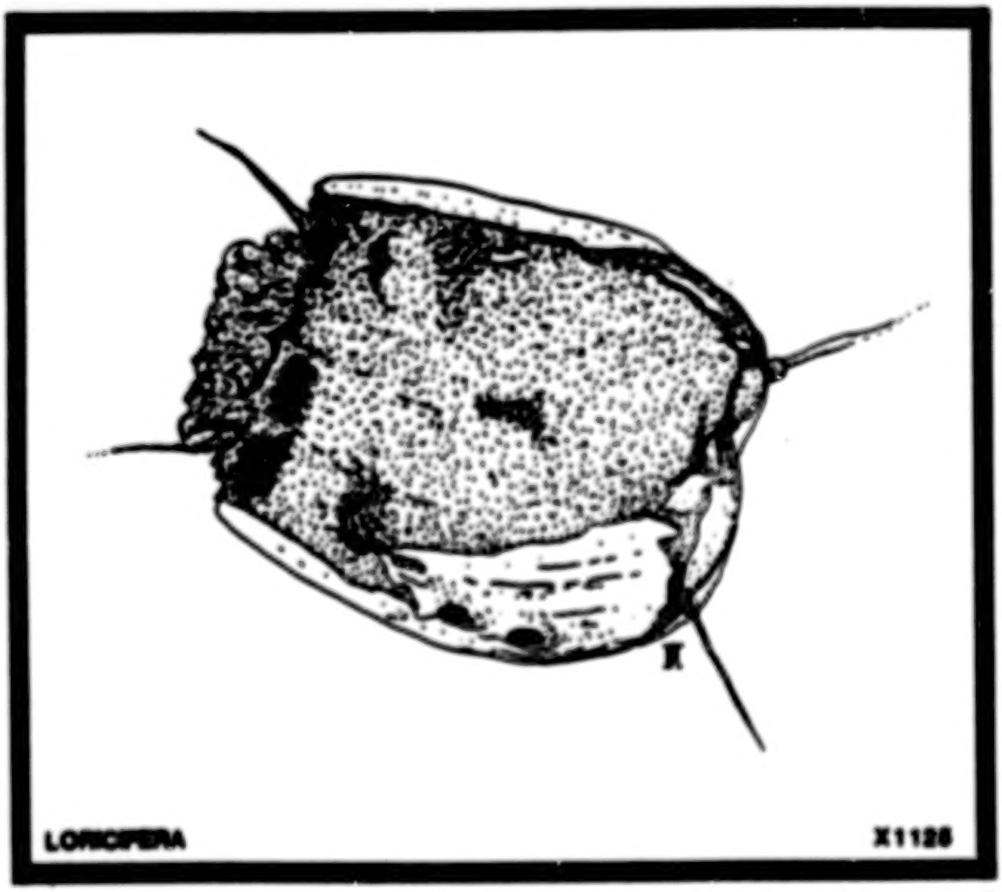

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Minerals Management Service
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COVER:

In 1983, Reinhardt Kristensen of the University of Copenhagen, Denmark described a new phylum of animals, Loricifera, based upon specimens collected in 25 to 30-m depths near Roscoff, France; from 480-m deep waters near the Azores and from 15-m depths off Fort Pierce, Florida. This new phylum depicted on the cover was found to be well represented (506 specimens) across the entire continental slope of the northern Gulf of Mexico, from Florida to Texas, at depths from 298 to 2959 m.

OCS Study
MMS 87-0060

Northern Gulf of Mexico Continental Slope Study Annual Report Year 3

Volume II: Technical Report

Contributing Editors

Benny J. Gallaway
Larry R. Martin
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Prepared under MMS Contract 14-12-0001-30212

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1.0 INTRODUCTION

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1.0 INTRODUCTION

Since 1983, LGL Ecological Research Associates, Inc. (LGL) in conjunction with Texas A&M University (TAMU) has been conducting a study of the continental slope of the northern Gulf of Mexico for the Gulf of Mexico Regional Office of the Minerals Management Service (MMS). The overall objective of the program is to develop a basic knowledge of the deep Gulf fauna, their environment, and ecological processes in advance of extensive petroleum development.

Prior to initiation of this study, MMS had funded TerEco Corporation Inc. to synthesize all available environmental information for the Gulf slope. The resulting report (Pequegnat 1983) described and interpreted information through 1982, and, in large part, served as the basis for formulating the objectives of the present program. The Pequegnat (1983) document thus provided the background or baseline data against which the information gathered by this study can be compared and evaluated.

1.1 PROGRAM OBJECTIVES AND CONTENT OF THIS REPORT

The specific objectives of the Gulf of Mexico Continental Slope Study are:

(1) To determine the abundance, structure, and distribution of animal communities in the deep-sea in the Gulf of Mexico.

(2) To determine the hydrographic structure of the water column and bottom conditions at selected sites within the study area.

(3) To determine and compare sedimentary characteristics at selected sites within the study area.

(4) To relate differences in biological communities to hydrographic, sedimentary, and geographic variables.

(5) To assess seasonal changes in deep-sea biological communities in terms of abundance, structure, animal size, and reproductive state.

(6) To measure present levels of hydrocarbon contamination in the deep-sea sediments and selected animals prior to, and in anticipation of, petroleum resource development beyond the shelf-slope break.

(7) To assemble together and synthesize appropriate published and unpublished data with the results of this study, summarizing on a seasonal and spatial basis all biological, habitat, and environmental observations and parameters.

(8) To compare the biological and non-biological characteristics of the deep Gulf of Mexico with that of other temperate and subtropical deep-sea regions.

(9) To assess the need for, and determine the type of studies to be conducted in future program efforts.

Two additional objectives were mainly met during the first two years of the program:

(10) To conduct an effective quality assurance and quality control program which insures that all data acquired are accurate and repeatable within standards normally required for each type of observation, measurement, or determination.

(11) To critically review, interpret, and analyze all observations and data acquired to redefine as necessary the research program in such a way as to avoid or minimize redundancy and to optimize the efficiency of all field, laboratory, and data management operations for future deep-sea studies sponsored by MMS in the Gulf of Mexico.

Activities during Years 1 and 2 were dedicated to field sampling and laboratory sample analyses. Year 3 has been dedicated to finishing the sample analyses, and compiling the data in usable and interactive format.

The acquisition of data for meeting the stated objectives occurred over the course of five cruises, all conducted during the first two years of the program. Because of the small size and taxonomic complexity of the macrofauna, all of contract Years 1-3 (1983-1986), as well as a time extension into 1987, were required to complete sample analysis. This report represents the first time that all data have been available for analysis.

The primary goals of the Year 3 Annual Report were to (1) provide a detailed description of all the field collection, laboratory analyses and data management methods that have been used (this volume), and (2) provide a comprehensive summary, in hard copy, of all the data that were collected and that have been submitted to NODC in specified tape report (Volume III Appendices). In the Year 4 Final Report, emphasis will be placed upon statistical analyses, interpretation and reporting of the findings, and only summary descriptions of the methods and data detailed herein will be included in that report, mainly by reference.

In this report we present results of some initial exploratory analyses, we purposefully provide little in the way of interpretative comment. The Year 3 Annual Report has, as an analogy, the results section of a standard scientific paper. Following the same analogy, discussion of the results in terms of program objectives will be the focus of the Final Report for Year 4.

1.2 PROGRAM DESIGN AND INTEGRATION

As discussed above, this report is a descriptive treatise, that may appear to the reader to be a curious collection of disjointed results. The purpose of this section is to clarify how the results will be integrated for the Final Report planned for Year 4.

1.2.1 PROGRAM SAMPLING DESIGN

The program sampling plan was structured to first (based upon sampling conducted on Cruises I, II, III (in part) and IV (in part) compare environmental and biological attributes of the slope, by depth, among planning regions (Eastern, Central and Western Gulf, for site maps see Panels A, B and C of Fig. 2-1, Section 2) between seasons (fall versus spring), and between years (1983-84, 1984-85) by season (fall, spring, respectively) (Fig. 1-1). The depth selections were not random or evenly spaced down the slope but were rather the approximate mid-points of previously-defined (Pequegnat 1983) biological depth assemblages or "zones" (Fig. 1-2), namely (1) the Shelf-Slope Transition Zone (150 to 450 m); (2) Horizon A of the Archibenthal Zone (475-740 m); (3) Horizon B of the Archibenthic Zone (775-950 m); (4) the Upper Abyssal Zone (975-2250 m); and (5) the Mesoabyssal Zone, Horizon C (2275-2700 m). The purpose here was not to either prove or disprove the concept of zonation versus a continuation of change with depth, but rather to evaluate the predictive value of the Pequegnat (1987) zonation scheme.

The same five stations on the Central Transect were sampled in fall 1983, spring 1984 and fall 1984. On the spring 1984 cruise, the same depth intervals sampled on the Central Transect were sampled on both an Eastern and Western Gulf transect, and in spring 1985 the stations comprising the Eastern Transect were resampled. The design thus allows a sequence of specific contrasts, proceeding from comparisons by region, to season within region, to year within season to depth patterns within region, season and year. Our basic depth comparison strategy will be to first contrast the Shelf/Slope Transition station to the deeper slope stations. The next basic division will be to contrast variables for stations located in depths shallower than 1000 m to those located deeper than 1000 m. This depth, or thereabouts, has long been viewed as a major break in the slope environment as it is here that light from the surface can no longer be distinguished and that temperature becomes uniformly cold (≤ 4°C). The last contrasts will be made between the two depths corresponding to Pequegnat's (1983) defined assemblages within the shallow (< 1000 m) and deep (> 1000 m) categories. In contrast, according to Carney et al. (1983), we should find only (1) a distinct shelf fauna above 1000 m, (2) a distinct abyssal fauna below 2000 m, and (3) in between, an indistinct slope fauna that is partially obscured by immigration from the two larger areas shallower and deeper (Fig. 1-2).

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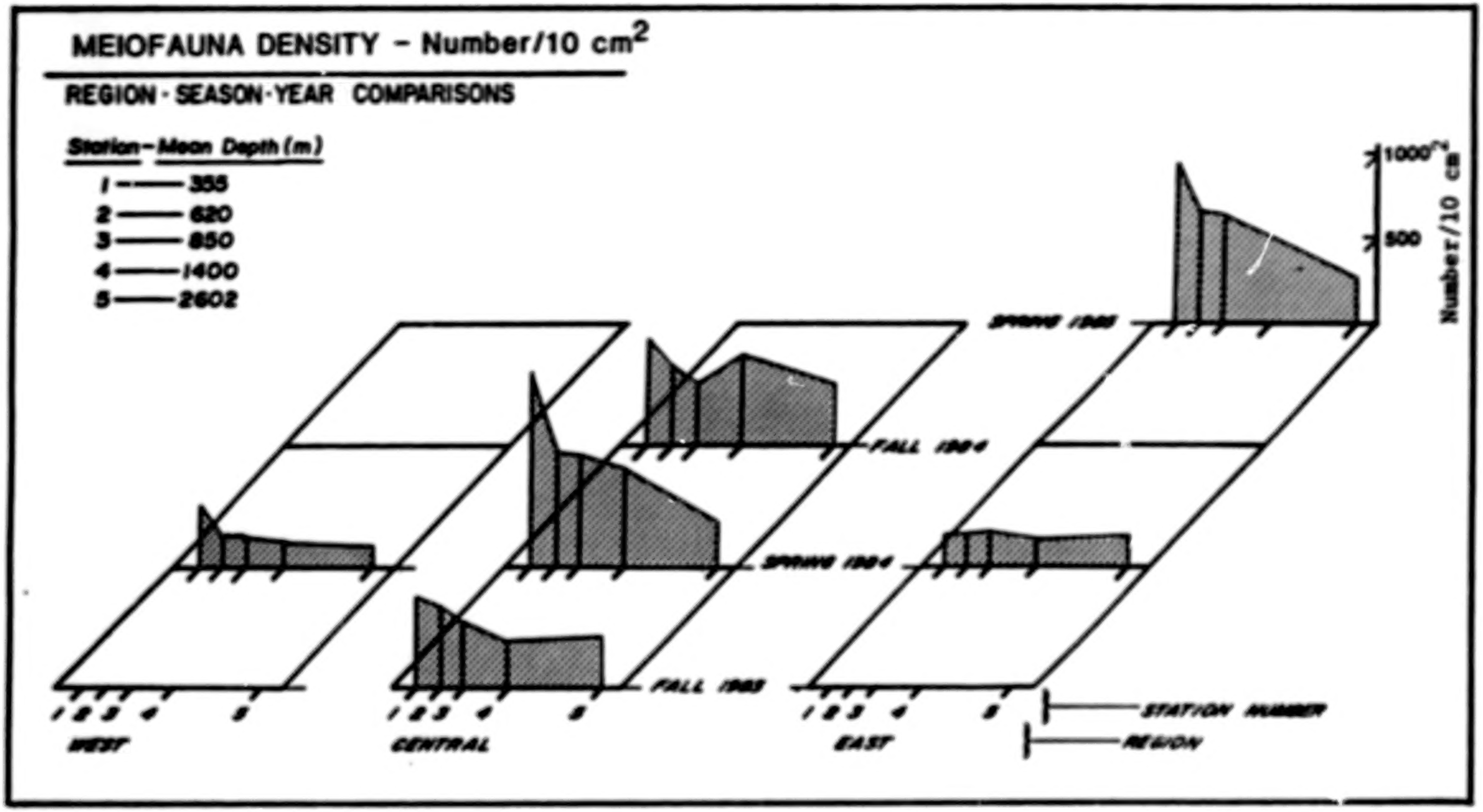

Figure 1-1. Analysis design diagram for region, season and year comparisons based upon samples taken at selected depths, using density as the example response variable. Each tick mark represents the sample locations in time and space.

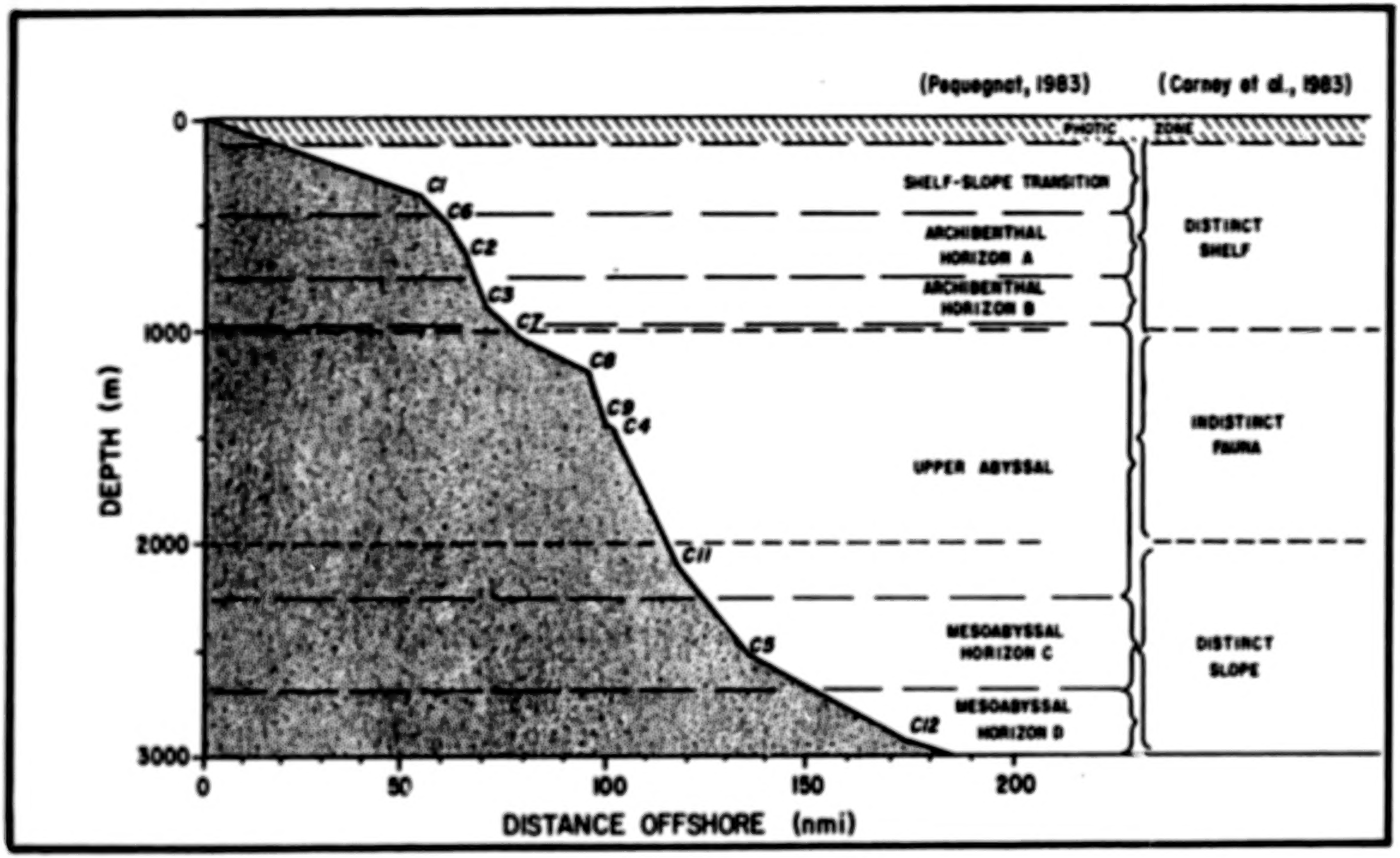

Figure 1-2. Two contrasting views of the expected faunal changes that might be observed on the continental slope of the northern Gulf of Mexico. C1-C12 represent stations sampled in this program during Fall 1985.

The sampling design for Cruise III was focused towards evaluating and testing selected zonation hypotheses (e.g., Carney et al. 1983 versus Pequegnat 1983, Fig. 1-2). Twelve stations were sampled on the Central Transect at depths of 356, 492, 633, 881, 1017, 1191, 1428, 1465, 2100, 2518 and 2945. A site map is provided in Panel C of Figure 2-1, Section 2; an analysis design diagram is shown by Figure 1-3.

The first contrast will be to test the hypotheses of a real break at about 1000 m by comparing data taken at the first four (356 to 881 m) depths to data taken at the deeper depths (1017 to 2945 m). Within the shallow group of stations, we can then compare the hypothesized Shelf-Slope Transition Zone to the Archibenthal Zone and; lastly, between the two depths within each zone. Given the relatively even spacing among these more shallow stations, this sequence of contrasts should delineate between the dichotomous views of sharp faunal breaks (zones) versus a more conservative view of the nature of changes with depth.

The next contrast will be to compare variables at depths equating to Pequegnat's (1983) Upper Abyssal Zone versus those equating to his Mesoabyssal Zone; and for the latter, between the two hypothesized horizons. These should not be different according to the Carney et al. (1983) concept (Fig. 1-2).

At this point we will be left with the stations between 1000 and 2000 m. The first step will be to contrast the ~2000-m deep station which, although within the Upper Abyssal Zone, was widely separated from the other stations (• sampled depths). We will next compare the two shallower sites within the zone (881, 1017 m) to the deeper sites (1428, 1465 m), and then make comparisons between the individual depths within the two sets. The shallower set was more widely spread than the deeper set (see Figs. 1-2 and 1-3), thereby providing a test of the hypothesis that differences are mainly a function of distance between sites when placed along a depth gradient.

The sampling regimes for Cruises IV (Eastern Gulf) and V (Western Gulf) had similar objectives but for different regions. The overall goals were to sample along given isobaths to determine the degree of longitudinal or latitudinal variation as compared to depth variation, and

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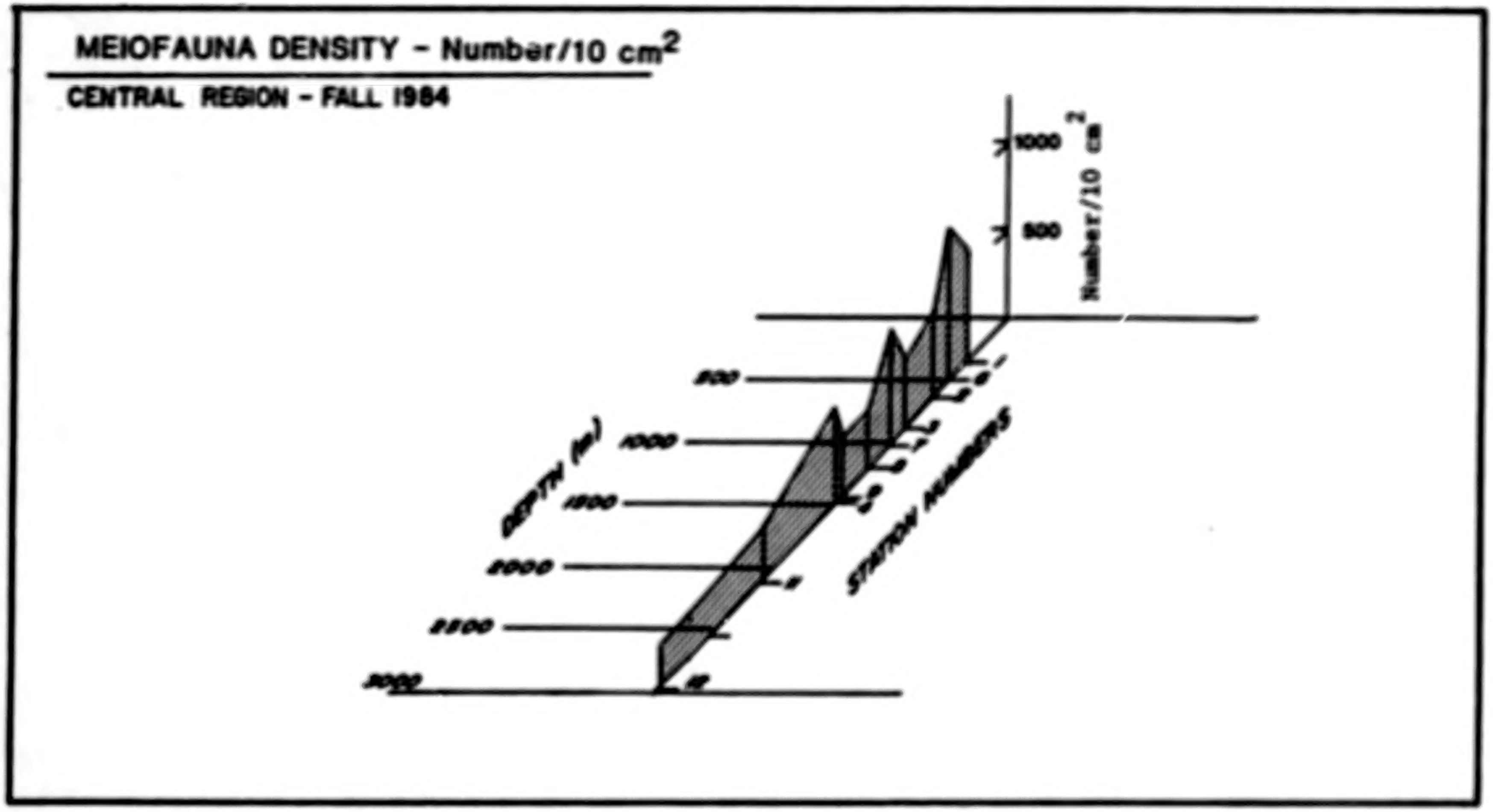

Figure 1-3. Analysis design diagram for zonation studies using density as the example response variable. See also Figure 1-2 for relationship of sampling stations to hypothesized faunal zones.

to determine some of the sources of the observed variation by means of specific contrasts (e.g., sandy bottom areas versus silt and clay bottoms, petroleum seep areas versus non-seep areas, topographic attributes, etc.).

In the Eastern Gulf, the selected depths (Fig. 1-4, see also Fig. 2-1, Panel D, Section 2 for site map) were ~350 m (four stations), 625 m (six stations), 850 m (five stations), and 2900 m (one station). Once more, the first step will be to compare the Shelf-Slope Transition Zone (350-m deep stations) to "true" slope habitats. Next, the 2900-m deep station (Mesoabyssal, Horizon D) will be contrasted to those of the mid-slope Archibenthal Zone, Horizons A (625 m) and B (855 m). These contrasts will be followed by a comparison of Horizons A and B within the Archibenthal Zone.

Within the Shelf-Slope Transition stations, one (E1A) was located on a silty-clay bottom whereas the others (E1B, E1 and E1C) were all sited, by design, on sand-silt-clay bottoms. This provides the basis for the initial contrast among these stations--the effects of sediment grain size. Next, the centrally-located station (E1) will be compared to the flanking stations E1B and E1C. And finally, the two distal stations will be contrasted. This sequence of tests will enable an evaluation of the effects of distance on observed biological differences along an isobath.

The placement of stations along the 625-m depth contours were all on the same sediment type, but three stations (2B, 2 and 2C) were tightly grouped as a core, with one station (2A) widely spaced from these to the northwest and two stations (2D and 2E) separated to the southeast. This provides the basis for the first contrast within this group of stations. Within the core group of stations, E2C was farthest removed from the other two and data from this station will be contrasted to data for E2 and E2B, which will then be compared to each other. Lastly, for this sequence of comparisons, the stations at the opposite ends of the transect will be compared, namely information for station E2A versus E2D and E2E combined, and then the latter versus one another. The results of these analyses should yield information enabling one to evaluate whether variation along an isobath is equivalent to variation observed on the vertical depth scale.

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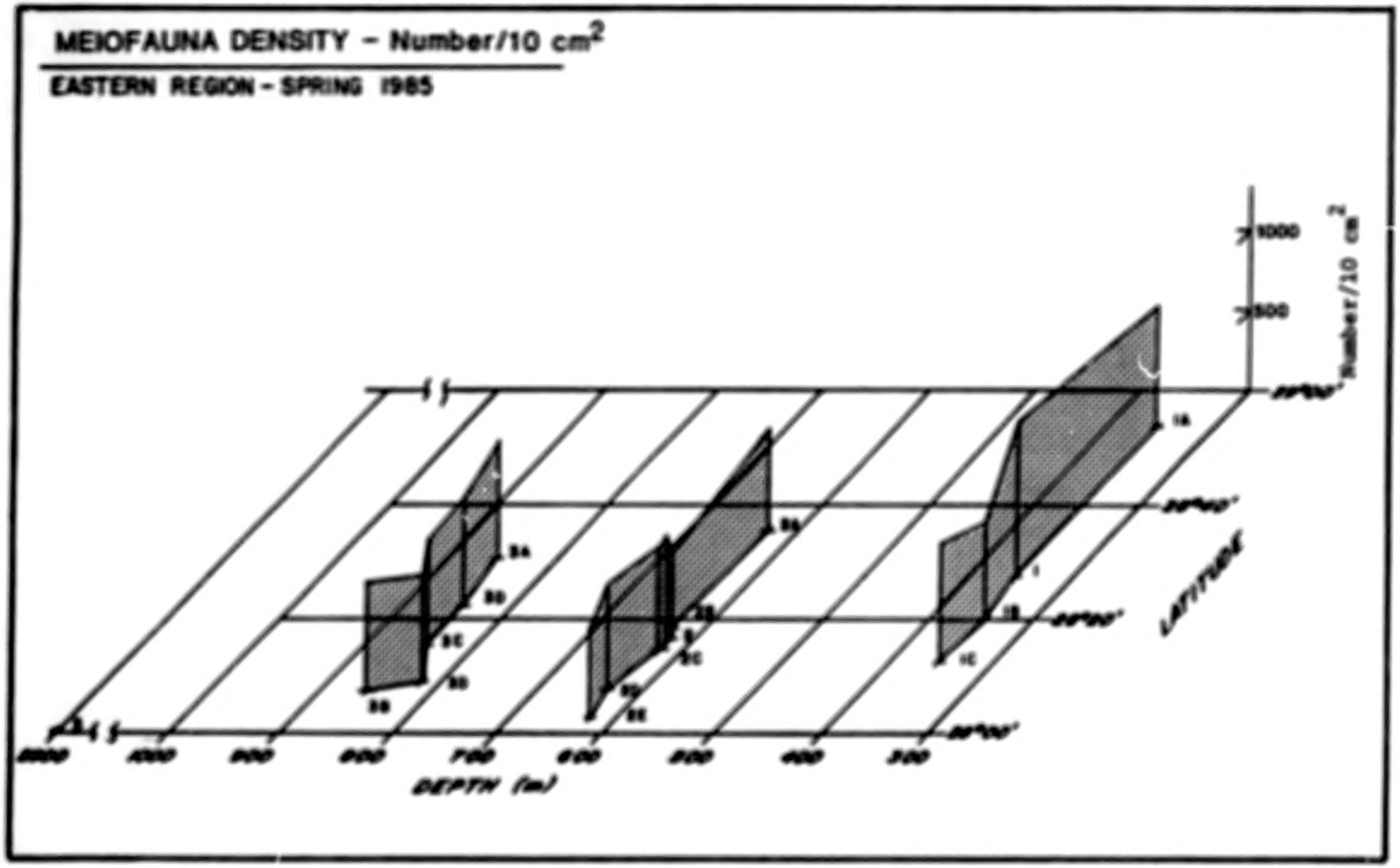

Figure 1-4. Analysis design diagram for samples taken in the Eastern Gulf in spring 1985 to examine latitudinal versus depth variation in samples taken at selected depths. Density is used as the example response variable.

The station array for the 825-m deep stations enables an evaluation of the effects of latitude along an isobath. Here, stations E3B (28°02') and E3 (28°09') were the most southerly, and variables from these areas will be contrasted with information from stations E3C (28°15'), E3D (28°21') and E3A (28°29') treated as a group. Data from E3B and E3 will then be contrasted to each other followed by a contrast of data for E3A to E3C and E3D. Lastly, information for E3C and E3D will be contrasted as a measure of fine-scale latitudinal differences.

The isobathic sampling in the Western Gulf was conducted between the previously sampled Central and Western Transects, and stations included were given a WC (West-Central) prefix (see Fig. 2-1, Panel D, Section 2 for site map). An analysis design diagram is provided by Figure 1-5. Of the 12 stations sampled, two (WC1 and WC5) were in the hypothesized Shelf-Slope Transition Zone (150-450 m); five (WC2, WC4, WC6, WC7 and WC8) were in Horizon A of the Archibenthal Zone (475-740 m); three (WC3, WC9 and WC10) were in Horizon B of the Archibenthal Zone (775 to 950 m); and two (WC11 and WC12) were in Horizon B of the Upper Abyssal Zone (975-2250 m), following Pequegnat (1983).

Following precedent, the first comparison will contrast the hypothesized Shelf-Slope Transition Zone to the stations deeper on the slope; and within the Shelf-Slope Transition Zone, a contrast of WC1 to WC5 enables an evaluation of the effects of sediment type (silty-clay versus sandy-clay). As before, we will then proceed to contrast the deepest stations (WC11, WC12) to the shallower stations on the slope proper (i.e., not including the transition zone). The contrast of WC11 (topographic low surrounded by shallower water) to WC12 (topographic high surrounded by deeper water) provides a direct examination of the effects of depth per se.

The next set of contrasts will be to address whether significant differences are apparent between the two hypothesized horizons within the Archibenthal Zone. Within Horizon A, a contrast of data for Stations WC6 and WC7 to the others in this zone (WC2, WC4 and WC8) provides an evaluation of areas with suspected petroleum seeps to areas believed to be devoid of any known petroleum seeps. The two seep areas will then be

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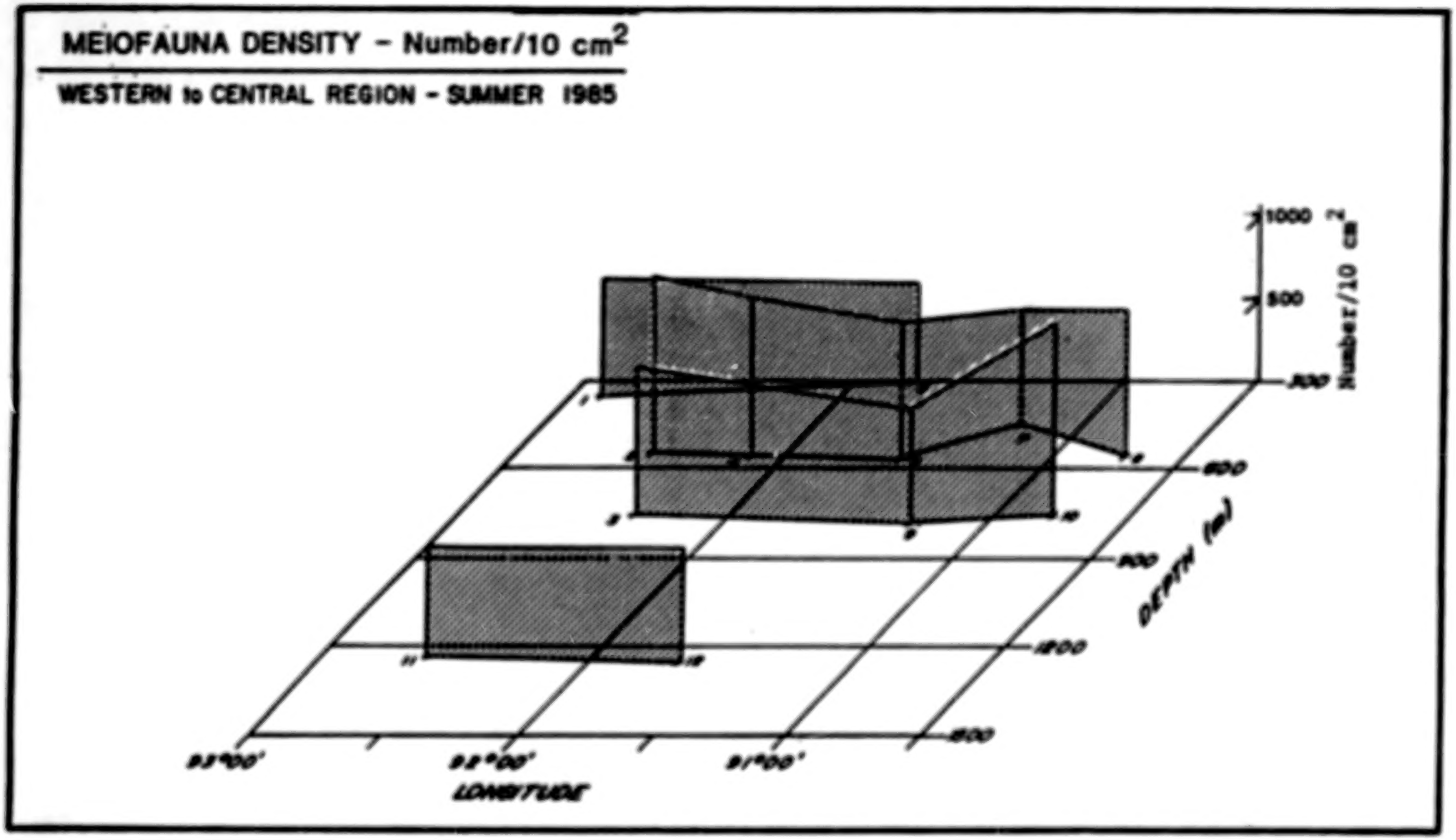

Figure 1-5. Analysis design diagram for samples taken between the Central and Western transects in summer 1985 to examine longitudinal versus depth variation in samples taken at selected depths. Density is used as the example response variable.

compared to each other; Station WC2 will be compared to WC4 and WC8; and WC4 will be compared to WC8. The latter contrasts will provide an estimate of longitudinal variation within the same depth range and sediment type. Within Horizon B, a contrast of WC3 to WC9 and WC10, and contrast of WC9 to WC10 will also provide an estimate of longitudinal variation within the same depth range and sediment type.

1.2.2 FINAL REPORT PLAN

In the Final Report, environmental (hydrography, sediment characteristics, hydrocarbon chemistry) and some biological data will be integrated to show how the slope habitat differs among regions, depths, seasons and years. Differences will be determined by inspection as well as by more quantitative means such as Principal Components Analyses (PCA). In our project design, we have up to 40 environmental or habitat variables that were measured as potential factors affecting biota. PCA enables one to transform a large original set of variables into a smaller set of combinations that account for most of the variance of the larger, original set. The purpose is thus to explain as much of the total variation in the data as possible, with as few of these factors as possible.

The outputs of PCA enables one to group entities (in our case, stations by depth, seasons and year) in terms of their physical/chemical attributes. This, in effect, provides an environmental classification against which we can compare results of various biological classifications of the same stations. The question being addressed by this approach is: Does the distribution and abundance patterns of biota on the slope correspond to environmental differences?

The biological analyses will first focus on each of the major taxonomic groups associated with soft bottom habitats, namely the meiofauna, macrofauna and megafauna, the latter of which were sampled using trawls as well as benthic photography.

The meiofauna section of the Final Report will describe the composition of the meiofauna by major group and numerical abundance patterns by season, region and depth. Differences will be evaluated by inspection because of the lack of any detailed taxonomic resolution. The abundance of meiofauna will be correlated to physical factors as well as to macrofauna abundance and biomass. Historically such contrasts have been used to depict overall community structure and a reflection of how this structure changes over depth (e.g., Thiel 1983). Based upon the above information, our findings will be compared to other regions, with any unique or unusual attributes of the Gulf meiofauna so identified.

The project meiofauna data set was the most complete of any project data set at the time this report was being prepared and the analyses presented in Section 4.1 are reasonably detailed. Nevertheless, the results presented herein are preliminary only, and do not represent the style and content which will be used in the Year 4 Final Report.

For each of the macrofauna and megafauna designations, the Final Report will first present an overview paper describing the species composition of the overall group and relative abundance patterns among species. Such descriptions will include species area and/or rarefaction curves as an index to assemblage structure. Seasonal and spatial (region and depth) patterns of diversity (Shannon-Wiener Index) will be described using Analysis of Variance (ANOVA) to detect significant differences and the contrast scheme detailed above (orthogonal contrasts) will be used to define the nature of the diversity differences by region, season and depth.

A number of diversity indices might be used, each having certain attributes and problems. All are influenced at least to some degree by sample size and all must be considered representative of the samples versus whole assemblages given known problems with sampling efficiencies of standard sampling devices (e.g., trawls and box corers) operated at great depths over different types of substrates. We have selected the Shannon-Wiener Index because (1) it has been demonstrated to be reasonably independent of sample size and, within limits, is normally distributed (Bowman et al. 1971) and, most importantly, (2) it has been previously used to define species diversity of the Continental Slope collections made in the northern Gulf of Mexico (Pequegnat 1983), allowing for direct comparisons.

The next step in the overview sections will be to apply cluster analysis techniques to biologically classify stations by region, season and depth for comparison, by inspection, to the classification scheme for the same stations yielded from PCA applied to physical/chemical attributes. Our cluster analysis approach will follow Grassle and Smith (1976) using a Normalized Expected Species Shared (NESS) as the similarity measure.

The findings of the described analyses will be compared to historical analyses of similar nature for other regions; and, in this context, any unusual attributes particular to the Gulf of Mexico will be identified. Also as part of the overview sections, we will identify the ecologically important or numerically dominant component groups within each of the macrofaunal and megafaunal designations. These groups will serve as subjects for a series of sections dealing with that group *per se*.

The same "community-type" analyses described above will be applied to the data for each major component group of the macro- and megafauna. In addition to these, we will also subject the species abundance data for depths and longitude to a chi-square analyses following Backus et al. (1965) and Gage (1986), designed to detect apparent faunal boundaries. By inspection and/or correlation, the findings will be related to distance between sampling sites.

In these sections of the Final Report, we will identify the most abundant species within the component groups and compare abundance patterns of these over time and space using ANOVA and orthogonal contrasts as defined above. An appropriate transformation will be applied to the data, if warranted, prior to the analyses. Likewise, correlation analyses will be conducted to determine the apparent associations of species abundance to physical/chemical attributes of the environment using data provided by the hydrography and sediment investigations. These discussions will also include a description of the present levels of hydrocarbons in animal tissues, as provided by the hydrocarbon chemistry studies.

Life-history accounts will be provided for numerically dominant or otherwise considered important species of megafauna. These will include discussion of food habits, size distribution, apparent growth patterns and length-weight relationships. For dominant macrofaunal species groups (e.g., the polychaetes) we will attempt to classify the populations by feeding type. All of this information is for the purpose of developing an overall conceptual model of the Continental Slope ecosystem. Some of the species accounts and feeding type information has already been developed and is included in this progress report as Attachments. The reader should bear in mind, however, that these accounts are not necessarily complete, and that no attempt is made herein to either interpret or integrate any of the information into a system context.

The Year 4 Final Report will also contain a section dealing with megafauna based upon our benthic photography surveys. While these results generally lack the taxonomic resolution required for many analyses, they have enabled an evaluation of the overall megafaunal densities estimated based upon trawling. Also, at least one very abundant species was photographed regularly that was never taken by trawling. These topics will be addressed in the Final Report, with the results, along with habitat observations, making major contribution to the system conceptual model. Many of the basic findings from the photography studies are presented in this report, but the reader is again forewarned, that little interpretation and no integration of the findings is attempted in this report.

As already mentioned above, none of the results of our chemosynthetic community investigations are addressed in this report, but a complete synthesis of information on these communities will appear in the Final Report, including results of project-specific studies.

The concluding section of the Year 4 Final Report will present a conceptual model of the Continental Slope ecosystem of the northern Gulf of Mexico, based upon an integration of all the program findings. In this section we will define the various types of assemblages that are represented and identify the energy sources and flows within and among assemblages. We will also identify areas of major uncertainties about the system and how these might be addressed by future studies.

1.3 GUIDE TO AND NATURE OF THIS REPORT

In the following sections of this report we first describe the study area and detail our study methods (Section 2.0). We next describe the results of the physical/chemical oceanographic studies on a geographic and seasonal basis (Section 3.0) of this report. It should be noted that the hydrocarbon part of Section 3.0 is a reprint of the same material that was presented in the final Year 2 Annual Report. It is reprinted (as previously approved for the Year 2 Annual Report) only for the sake of completeness. In Section 4.0, we provide our updated biological oceanographic results, and in Section 5.0, the updated results of the benthic photography studies are presented. References are provided as Section 6.0 and various attachments are included as Section 7.0. An Executive Summary is provided under separate cover (Volume I). Complete data listings are also provided under separate cover as the Appendices (Volume III).

During Year 3, submersible studies were conducted at selected sites where chemosynthetic seep communities were believed to be present. The results of these program studies will be provided as a separate report which, along with a synthesis of all other available information concerning Gulf of Mexico seep communities, will be incorporated in the Year 4 Final Report.

Some final introductory comments are in order here. Various sections of this report have been prepared by one or more of 12 individuals representing two institutions. Because of the preliminary and progress report nature of this volume, a major effort has not been given to standardization of data presentation, graphics and tables or consistency of text among sections. By program design, emphasis to this date has been placed upon quality assurance of the sample analyses and data compilation as opposed to data analysis, interpretation and the preparation of this report. With these observations in mind, we ask the reader's indulgence. However, despite the inconsistencies in style and content, we believe the discerning reader will find this report informative.

2.0 STUDY AREA AND METHODS

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2.0 STUDY AREA AND METHODS

The Request for Proposal for this study limited the program to waters north of 25°N having depths between 200 and 2600 m. It was further specified that stations were to be located in depths likely to "delineate faunal zonation or areas of transition" and that sampling stations were to be located in each of the Minerals Management Service (MMS) Western, Eastern, and Central Gulf of Mexico Lease Planning Areas. Guidance was also provided to all potential contractors as to the general level of research effort being anticipated by MMS, the general categories of samples to be collected and the nature of the kinds of laboratory analyses which MMS believed appropriate.

The Statement of Work for the first two years of sampling defined the allocation of work as one cruise to the Central Lease Planning Area during fall-winter of 1983, sampling of all three Lease Planning Areas during spring-summer of 1984, and intensive sampling of the Central Lease Planning Area during fall-winter of 1984. These requirements provide a context for the study area and methods descriptions provided below.

2.1 STUDY AREA

As required, the sampling strategy included surveying stations in each of the three MMS Gulf of Mexico Lease Planning Areas. The stations were initially located on down-slope transects, although these transects were later expanded laterally by additional stations. The locations of the transects and stations are shown in Figure 2-1, and a summary of the rationale for their selection is outlined below. A few characteristics of each lease planning area, and the approximate positions of the original three transects that formed the nucleus of the sampling plan are:

1. Central Lease Planning Area - This transect extended across the slope in the vicinity of the Mississippi Trough, from approximately [illegible]°20'N, 89°40'W to 26°40'N, 89°20'W. The area is characterized by extremely active sediment movement, relatively high terrigenous inputs, an

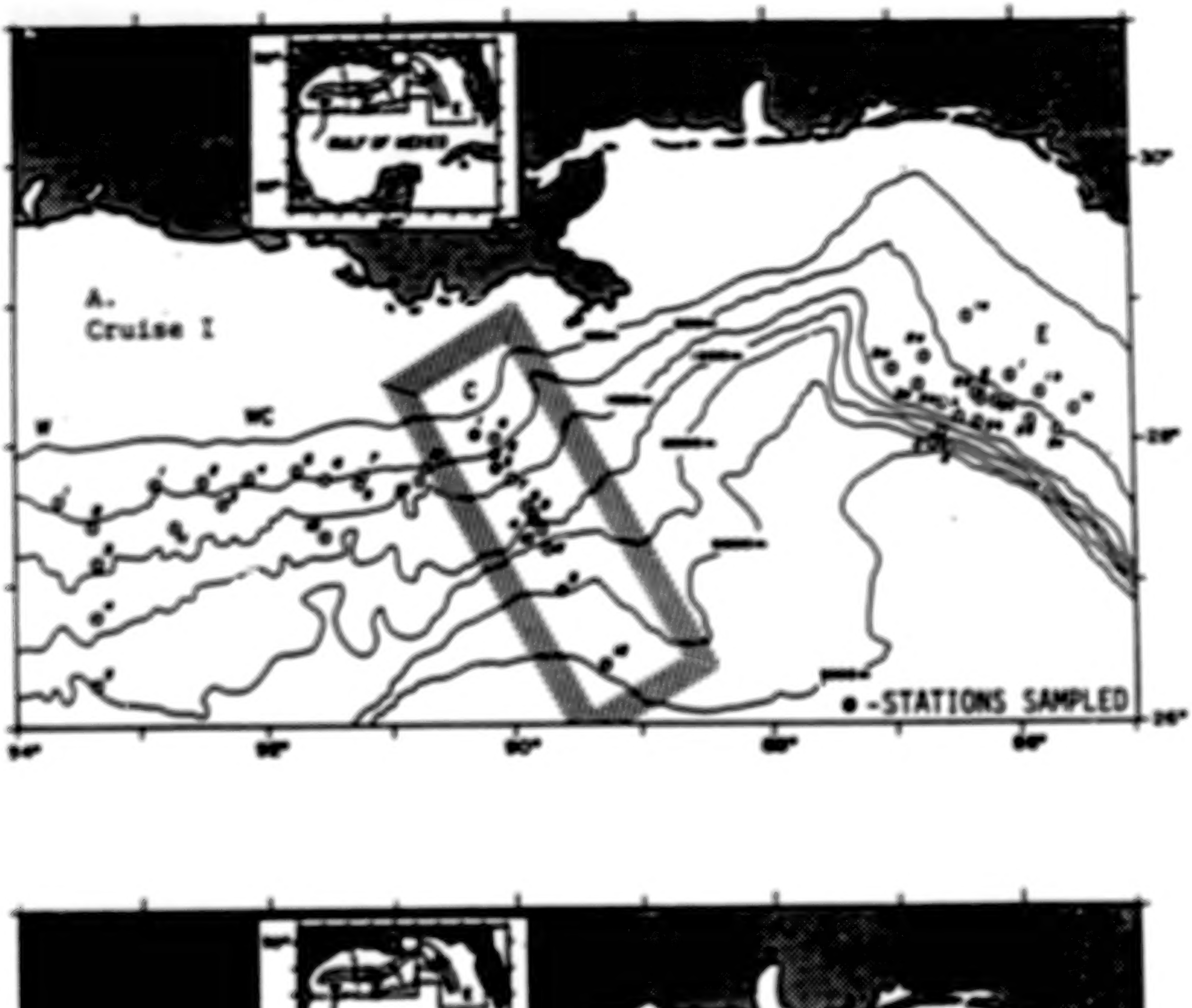

Figure 2-1. Stations sampled on each cruise.

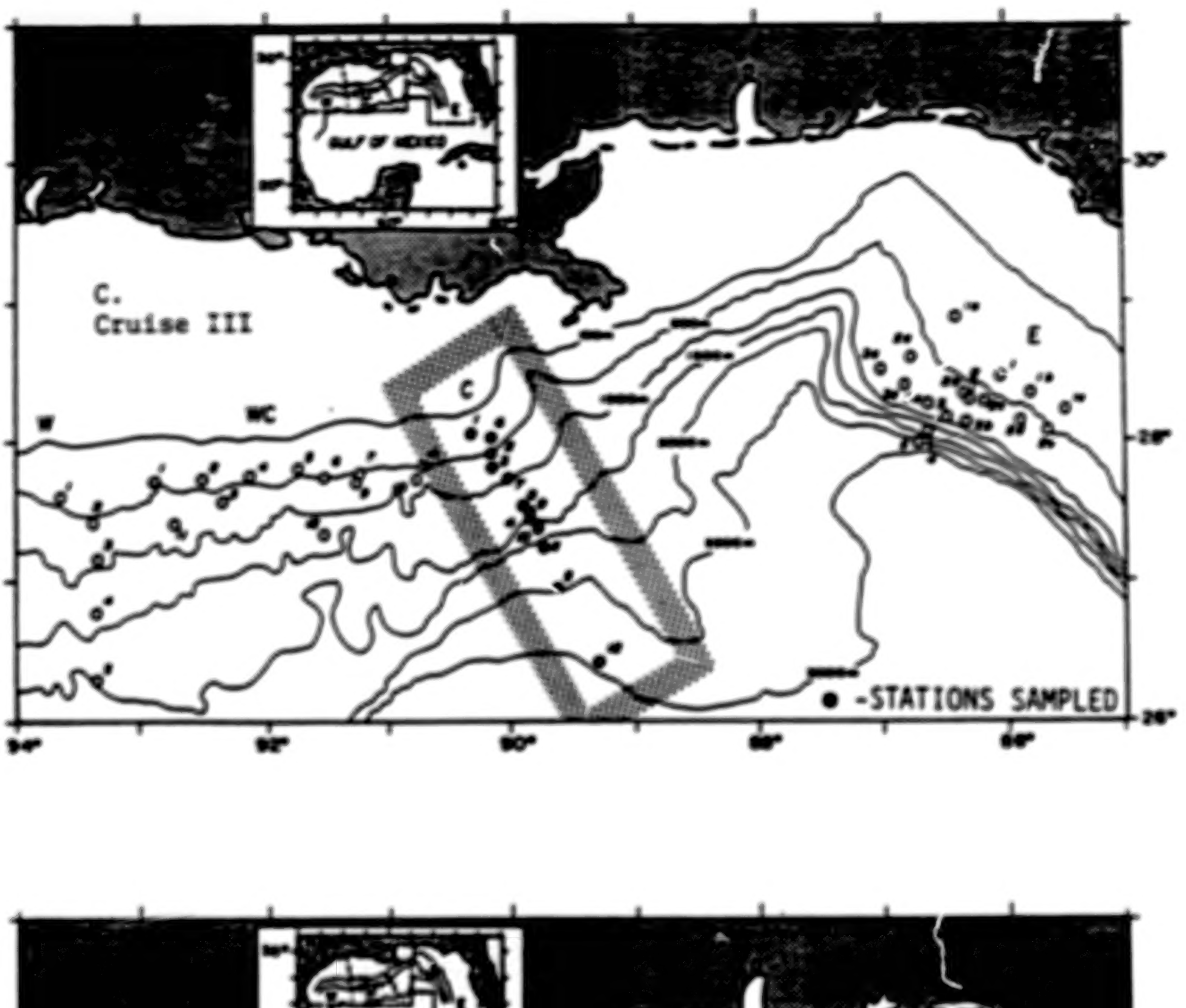

Figure 2-1 (cont'd).

absence of topographic features, and is occasionally bathed by the Loop Current.

2. Western Lease Planning Area - This transect extended across the slope just south of the Flower Garden Banks, from 27°25'N, 93°40'W to 25°50'N, 93°30'W. The area is characterized by the relatively sluggish circulation of the western Gulf, a number of pronounced topographic features, moderate to low declivity compared to the Mississippi Trough Transect. A fair amount of data is available from proximal areas.
3. Eastern Lease Planning Area - This transect crossed the Florida Escarpment from 27°40'N, 85°15'W to 27°30'N, 85°40'W. The area is characterized by high declivity (especially on the lower slope), a low rate of terrigenous input and sedimentation, and by moderate to strong currents along the face of the slope.

Station locations within each faunal zone were also influenced by water mass distribution and characteristics. The shallowest station in each transect was located towards the deeper end of the Shelf/Slope Transition Faunal Zone, below the zone of Gulf Common Water in Tropical Atlantic Central Water. Going down-slope, the next two stations were located in the Antarctic Intermediate Water mass, and the two deepest stations were in the Gulf Deep Water. Variation in water mass properties would be expected to be minimal at the deeper stations with the exception of events related to the passage of cold- and warm-core rings from the Loop Current.

2.2 CRUISES

On Cruise I, five stations at five different depths in the Central Gulf were sampled on the Central Transect during fall 1983 (Fig. 2-1A). The primary purpose of Cruise I was to provide a first look at the study area within previously-defined faunal zones over a wide depth range (300 to 2400 m), and provide data which could be used to refine future sampling and modify project hypotheses if necessary.

Cruise II, conducted during spring/summer 1984, extended the geographic coverage to the western and eastern regions of the Gulf, and re-sampled the stations occupied on Cruise I (Fig. 2-1B). Based on results of Cruise II, comparisons could be made among geographic areas and depths, as well as between seasons for stations on the Central Transect.

During Cruise III, the five original Central Transect stations were sampled again in fall 1984, along with seven additional stations (Fig. 2-1C). The seven new stations were located on the Central Transect at different depths from the first five stations. The locations for the additional stations were mainly in suspected transition areas and were based upon the advice of the Scientific Advisory Committee. Sampling the five original Central Transect stations allowed annual comparisons between the fall cruises of 1983 and 1984.

During the spring/summer 1985 Cruise IV, 16 stations were sampled near the Eastern Transect, including those previously occupied on the Eastern Transect on Cruise II (Fig. 2-1D). The new stations were grouped by depth at approximately 350 m (4 stations), 625 m (6 stations), 850 m (5 stations), and 2900 m (1 station). The intention was to examine depth-related differences in the context of observed variability along depth contours. Annual variability could also be studied by comparing the data from Stations E1, E2, E3, and E5 on Cruise IV to data from Cruise II, when the same stations were visited a year earlier.

Station locations for Cruise V (Fig. 2-1D), also conducted during spring/summer 1985, were chosen on the basis of several criteria. The area between the Western and Central Transects was subject to ongoing and expected future oil and gas exploration and development activities. Many sites were selected along depth contours in order to offer wide geographic coverage of the area and to document within-depth variability in sediment and biological characteristics. Hydrocarbon seeps had also been reported in the area, and the associated biota had not been well documented. Two suspected areas of hydrocarbon seeps (Stations WC6 and WC7) were thus chosen to compare with probable "control" (non-seep) areas at comparable depths (Stations WC8 and WC2).

The sampling strategy described above permitted project scientists to make the following basic contrasts:

Contrast	Data Source
Seasonal variation by depth	Central Transect, Cruises I & II
Geographic variation by depth	Western, Central, and Eastern Transects, Cruise II
Annual variation by depth	Central Transect, Cruises I & III
Zonation patterns	Central Transect, Cruise III, plus data from all other cruises
Variation within depths, Western Gulf	West-Central Transect, Cruise V
Variation within depths, Eastern Gulf	Eastern Transect, Cruise IV

2.3 METHODS

2.3.1 FIELD METHODS

2.3.1.1 Hydrographic Measurements

Continuous and discrete measurements of hydrographic parameters were obtained throughout the water column (surface to bottom) at five stations on each cruise. A Neil-Brown Mark III CTD/Rosette/Transmissometer System was used to obtain continuous data and discrete water samples. Continuous conductivity (salinity), temperature, depth, and transmission records were provided by the Neil-Brown CTD. A 12-bottle rosette attached to the CTD was used to collect at least 12 discrete water samples at each station. Bottles were spaced throughout the water column in order to delineate the major water masses at each site. The CTD/Rosette/ Transmissometer system was deployed with a pinger so that the cast could be safely lowered to within a few meters of the bottom. This was done in order to discern whether there were bottom nepheloid layers at each site.

Continuous Measurements

The shipboard Neil-Brown CTD system consisted of a demodulator, digital display and digital-to-analog converters. Digital output of each scan (every 32 ms) was transmitted via armored cable to the shipboard unit in "TELETYPE" format using frequency-shift-keyed modulation designed to transmit up to 127 bytes (8 bits) per scan.

The housing with the conductivity, temperature, and pressure sensors was pressure tested to 10,000 psi for one hour. The range, accuracy and resolution of the individual sensors were:

SENSOR TYPE	RANGE	ACCURACY	RESOLUTION
Pressure	0-320 decibar 0-650 decibar 0-1600 decibar 0-3200 decibar 0-6500 decibar	0.1% of FS (standard) 0.5% (optional)	0.0015% FS (all ranges)
Temperature	-32 to +32°C	0.005°C (-3 to +32°C)	0.0005°C
Conductivity	1 to 65 mmhos	0.005 mmhos	0.001 mmhos

Transmission profiles were provided by a Sea Tech Inc. transmissometer interfaced to the CTD system. This instrument has a 25 cm light path with a light emitting diode with a wavelength of 660 nm as a light source. This instrument, with proper calibration, provides data with an error less than 0.5% transmission. It has a depth capability of ca. 2500 m.

The data from the CTD/transmissometer were stored both as a hard copy from an X-Y recorder and on magnetic tape. An HP-1000 computer was used aboard the R/V *Gyre* for data storage.

Discrete Measurements

Discrete measurements of temperature, salinity, dissolved oxygen, nutrients, and particulate organic carbon (POC) were obtained by collecting samples from PVC Niskin bottles mounted on a General Oceanics Rosette sampler. Subsamples for dissolved oxygen were drawn first. All the discrete measurements were performed at sea. Measurements of temperature, salinity, and POC were all performed in duplicate. Ten percent of the oxygen and nutrient samples were also duplicated to establish sampling and analytical precision, and to assure data reliability.

Thermometry. Deep-sea reversing thermometers were attached to Niskin bottles mounted on the Rosette. These precisely calibrated thermometers were from Texas A&M University's Department of Oceanography collection. Most have long histories of calibration to ± 0.005°C. The thermometers were equilibrated at depth for at least 5 min before tripping. All thermometers were equilibrated read in duplicate by separate observers.

Salinity. Samples for salinity were collected in 500-ml airtight citrate bottles that were rinsed three times with sample water before collection. Samples taken from salinity were analyzed using either a Plessey Environmental Systems Model 6230N Laboratory Salinometer or a Guildline Model 8400 Autosal Laboratory Salinometer. The Plessey system utilized an inductively-coupled conductivity sensor to establish a conductivity ratio between an unknown sample and a standard at approximately 35 ppt salinity. A dual-element platinum thermometer and its associated circuitry sensed the temperature of the sample and applied the appropriate compensation. The Plessey system had a range of 0 to 55 ppt, with an accuracy of ± 0.003 ppt, and temperature compensation of ± 0.0007 ppt/°C. The Autosal system measured conductivity directly and had better accuracy and precision than did the Plessey system.

Oxygen. Oxygen samples were always the first samples drawn from a cast, and were drawn as soon as possible. The samples were taken using a length of Tygon tubing with the tip of the tube near the bottom on the flask so that it could be filled slowly without agitation. The flask was rinsed and air bubbles removed from the tubing with a small amount of sample before the flask was filled. The flask was overflowed one full volume and the stopper inserted to avoid trapping air bubbles.

The technique used for analysis of oxygen was the modified Winkler technique of Carpenter (1965). Oxygen samples were analyzed at sea. At least 10% of the oxygen samples were taken and analyzed in duplicate. A summary of the technique follows:

> As soon as possible after collection, the samples are "pickled" by the addition of a divalent manganese solution, followed by strong alkali. The precipitated manganous hydroxide is dispersed evenly throughout the seawater sample, which completely fills a stoppered oxygen flask. Any dissolved oxygen rapidly oxidizes an equivalent amount of divalent manganese to basic hydroxides of higher valency states. When the solution is acidified in the presence of iodide, the oxidized manganese again reverts to the divalent state, and an amount of iodine directly proportional to the original dissolved oxygen content of the water is liberated. The iodine is titrated with standardized sodium thiosulfate per Strickland and Parsons (1972).

Nutrients. Water samples for nutrient analysis (phosphate, nitrate, nitrite, silicate) were drawn into "Whirl-Pak" sampling bags. If samples were not analyzed immediately, they were frozen until analysis later during the cruise. Generally, analyses were performed immediately in the field following the methods outlined by Strickland and Parsons (1972). Specific methods for each of the nutrients are also given by Technicon Instruments Corporation of Ardsley, New York, Industrial Methods Bulletins 100-70W, 98-70W, 161-71WB, and 155-71W.

2.3.1.2 Box Core Sampling

Box core samples were taken at each station to obtain material for macroinfauna and meiofauna identification; sediment grain size; carbonate; total organic carbon; carbon isotopes; and hydrocarbons. Six replicate samples were taken at each station, except on the Western and Eastern Transect stations during Cruise II, when only three replicates were taken per station. The replicates were then subdivided to provide material for the various types of analyses.

Box corers were deployed in yoked pairs, using a TAMU-modified version of the Gray-O'Hara modification of the J&O box corer. Under ideal conditions, only one cast was required to collect two replicates.

The box corer (Fig. 2-2) measured 24.5 x 24.5 x 44 cm. It was fitted with a hinged door to prevent washout of samples, and had up to 135 kg of ballast. The door was open until the device had penetrated the substrate, whereupon the jaws and the door closed. The amount of ballast was adjusted to ensure adequate substrate penetration.

The box corer contained six metal coring tubes, 43.5 cm long and 3.5 cm in internal diameter. During Cruise I, these tubes were mounted in three pairs on a wire rack in the center of the box. This design was improved on successive cruises by mounting all six tubes against one wall of the box and securing them behind an aluminum partition that extended the full depth of the box. As each box corer came onboard, the overlying water was carefully siphoned into the macrofauna container, and the remaining subsamples processed according to their intended uses.

Sediments for Physical and Chemical Analyses

Undisturbed, uncontaminated sediment samples for analysis of hydrocarbons, grain size, carbonate, and total organic carbon were subsampled from the box core immediately after decantation of overlying water. The subsample for hydrocarbon, carbonate and TOC analyses were stored frozen in a glass jar, while the samples for grain size analysis were placed in whirl-pak bags and refrigerated. All samples were appropriately labeled.

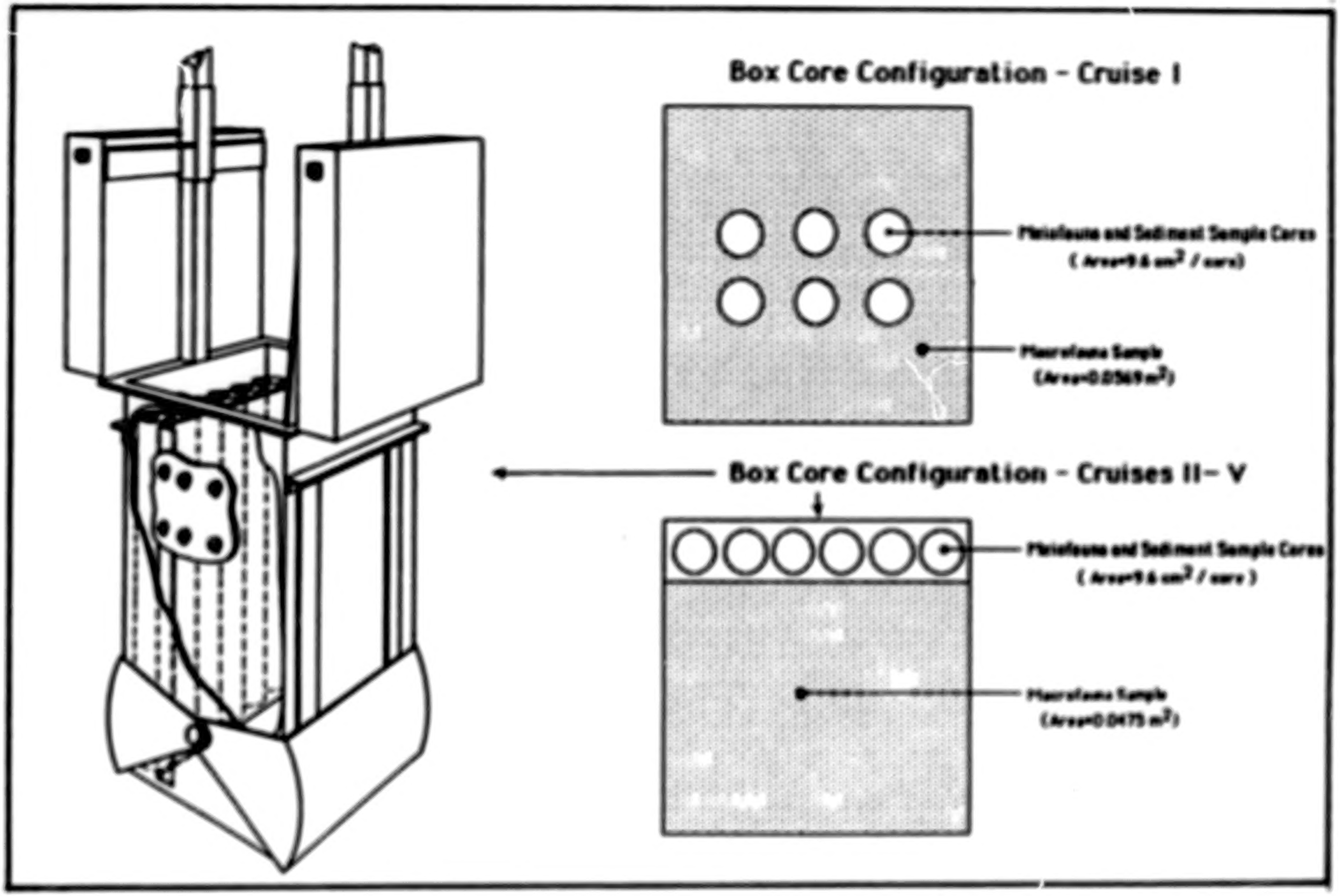
Box Core Configuration - Cruise I
Meiofauna and Sediment Sample Cores
(Area=9.6 cm² / core)
Macrofauna Sample
(Area=0.0569 m²)
Box Core Configuration - Cruises II- V
Meiofauna and Sediment Sample Cores
(Area=9.6 cm² / core)
Macrofauna Sample
(Area=0.0475 m²)

Figure 2-2. Box core and configuration of _in situ_ subsampling tubes in the box corer.

Meiofauna

Four of the tubes were used for meiofauna samples. The top five centimeters of sediment in the meiofaunal tubes was extruded using a plunger and placed directly into a glass or plastic sample jar. An isotonic solution of magnesium sulfate was immediately added to narcotize meiofaunal organisms. After the sample had been in a cool place out of the sun for about 30 min, it was preserved by adding neutral buffered formalin with rose bengal until the contents reached a concentration of 5% formalin. The jar was gently shaken to achieve a uniform mixture of the preservative. Preserved samples were stored at ambient temperature.

Macrofauna

The remainder of the box core contents was removed to a depth of 20 cm and washed carefully on a 300 micrometer sieve with a gentle stream of cartridge filtered sea water. Material retained on the screen was placed in suitable containers, labeled, and narcotized in an isotonic magnesium sulfate solution. Following narcotization, organisms were preserved in a solution of 10% neutral buffered formalin in sea water, to which rose-bengal stain was added. These samples were stored in a cool place as soon as possible following collection.

2.3.1.3 Trawl Sampling (Megafauna)

Megafauna sampling was performed with a standard 9-m, semi-balloon otter trawl with 60-cm steel doors, 3.8-cm stretch mesh, and 1.3-cm cod end mesh. Target trawling times were one hour at stations shallower than 1300 m, and two or more hours at deeper stations. The amount of time on the bottom was arbitrarily measured as the time from winch brake application until the winch was started again for trawl retrieval. At a towing speed of one to three knots, a ratio of 3.5:1 between amount of wire out and the depth produced good samples.

The contents of each retrieved trawl was dumped into metal tubs. Fishes and invertebrates intended for hydrocarbon assays were quickly removed, photographed, and frozen. The remaining organisms were usually rough-sorted into three categories (fish, decapods, and "other"). They were then narcotized with isotonic magnesium sulfate if necessary, and preserved in 10% neutral buffered formalin in sea water.

2.3.1.4 Benthic Photography

Benthic photography samples were obtained with the use of a Benthos Model 372 deep-sea camera fitted with a 28-mm lens (angle of view 35° x 48.5°), and equipped with a 200 watt-second Benthos strobe. On each visit to every station, the camera took 800 exposures of Kodak Ektachrome Professional 5936 film, ISO 200. Photographs were taken every eight seconds. A summary of the number of photos taken per transect summed over all cruises follows:

CRUISE/TRANSECT	NO. OF STATIONS	NO. OF PHOTOGRAPHS
I/Central	5	4,000
II/Western	5	4,000
II/Central	5	4,000
II/Eastern	5	4,000
III/Central	12	9,600
IV/Eastern	16	12,800
V/West Central	12	9,600
Total:	60	48,000

The photographic gear was mounted inside a protective framework similar to that of Woods Hole Oceanographic Institution's Mini-Angus (Fig. 2-3). The frame and its mounted components are called "BUCS" (Benthic Underwater Camera System) for convenience in this report. BUCS had a clock and altimeter that recorded the time and altitude above the bottom in the corner of each photograph. The altimeter had a resolution of ± 0.1 m.

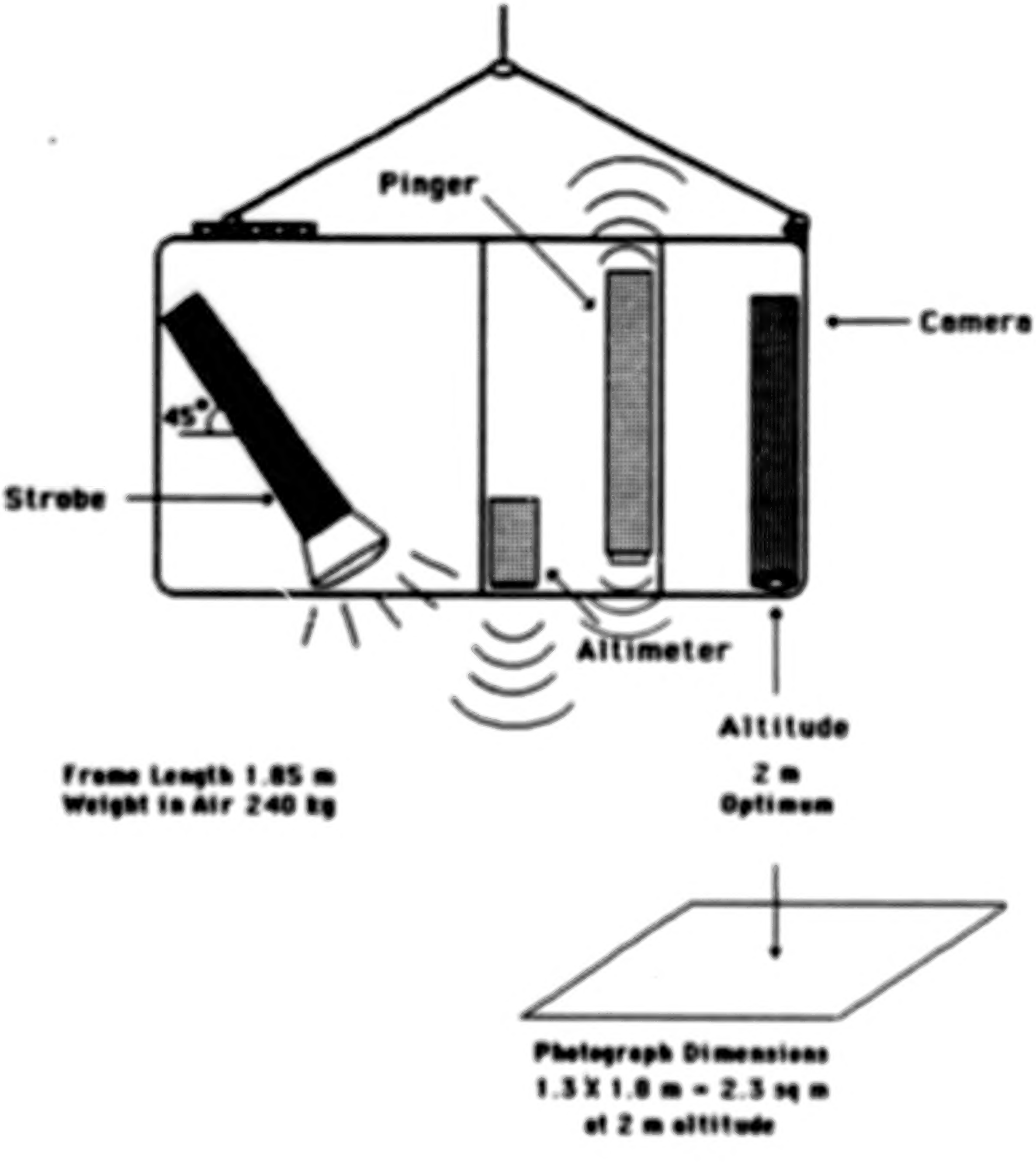

Figure 2-3. Schematic diagram of photographic system used for benthic photography.

BUCS was suspended from the vessel by a hydro wire, and allowed to drift near the bottom along transects 1500 to 5000 m long. Suspending BUCS in this way prevented skipping and bouncing on the bottom, thereby minimizing disturbance and reducing the chances of attracting or frightening animals away.

The plane of view was parallel to the bottom. Altitude was maintained by adjusting the vessel's winch in response to an acoustic signal transmitted by a 12 kHz bottom-finding pinger on BUCS. The signal was portrayed continuously on a strip chart recorder. Optimum camera altitude was approximately 2 m above the bottom, which produced shots that included 2.27 m^2 of the bottom. However, acceptable shots were obtained at altitudes from 0.7 m (0.27 m^2 area) to 4.0 m (9.09 m^2 area). At higher altitudes, larger areas were included in each shot, but image resolution was poorer; the converse was true at lower altitudes.

2.3.1.5 Quality Assurance and Quality Control (QA/QC)

Box Core Sampling

A concerted effort was made to obtain the highest quality samples. This effort included 1) using experienced and competent field biologists for sampling; 2) employing discrete criteria for quantifying the quality of each sample before it was accepted for on-board processing; 3) closely supervising sample handling, washing, narcotizing, and preliminary sorting; and 4) maintaining a sample tracking procedure to ensure proper chain-of-custody procedures.

In the field, the following criteria were used to judge whether a box core was acceptable:

1. The doors should be fully and properly closed;
2. The sediment in the box should be covered with clear water, because cloudy water suggests mixing of water and sediment during retrieval; and
3. The sediment should be level within the box, because sloping sediment suggests non-vertical sediment penetration.

Coring continued at each station until the requisite number of replicates met these criteria. For further information, please refer to Section 2.3.2.5 Quality Assurance and Quality Control (Laboratory).

Benthic Photography

All BUCS equipment was fully tested prior to each cruise. Fresh batteries were installed to power the 12 kHz bottom-finding pinger and camera data chamber. Nickel-cadmium batteries used in the high-intensity flash were drained and recharged to full capacity before every cruise, in order to prevent premature power loss during camera transects.

After each photographic transect was completed, a test strip of exposed film was developed while on station to confirm that no mechanical difficulties affecting the photography had occurred. The test strip was taken from the end of the 800-exposure roll, to determine whether or not the camera had exposed frames from the beginning to the end of the roll. If the test strip included an excessive number of poor shots, or if the photography had to be aborted while underway, the photographic transect was repeated at that station. That proved necessary on only two occasions, out of 60 transects completed.

2.3.2 LABORATORY METHODS

Laboratory activities included both physical/chemical and hydrocarbon determinations for sediments and biota; carbon isotope analyses for sediments and biota; sorting, identifying, enumerating and weighing, and measuring biota as well as analyzing their gut contents; and the analyses of photographs for biota and lebensspuren.

2.3.2.1 Sediment Samples from Box Cores

Grain Size

Sediment grain size followed the laboratory procedure of Folk (1974). Samples were homogenized and treated with an aliquot of 30% hydrogen peroxide (H_2O_2) to oxidize organic matter, then washed with distilled water to remove soluble salts. Sodium hexametaphosphate was added to deflocculate each sample. The samples were then wet-sieved using a 62.5 micron (4.0 0) sieve to separate the gravel and sand from the silt-clay fraction.

The total gravel and sand fraction was oven dried (40°C) weighed, and sieved at half-phi intervals (-1.5, -1.0, -0.5, 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0). Each collected fraction was examined for aggregates, disaggregated if necessary, and reweighed by fraction to three significant figures.

The silt-clay fraction was analyzed for particle size distribution by the pipette (settling rate) method at 4.5, 5.0, 5.5, 6.0, 7.0, 8.0, 9.0, and 10.0 phi intervals.

Organic Carbon

Organic carbon determinations were made using a Leco WR-12 Total Carbon System. Sediment subsamples (0.2-0.5 g) were weighed into disposable 5 ml polystyrene beakers and treated with concentrated HCl to remove inorganic carbon (carbonate). Acid was added dropwise until no degassing was observed. The treated samples were then dried at 50°C in a recirculating oven for 24-36 hours to remove excess acid and moisture. After drying, the sample was quantitatively transferred to a sintered crucible. Iron accelerator and tin coated copper catalyst were added and analyzed by total combustion on the Leco instrument. Organic carbon was converted to CO_2 and analyzed with a non-dispersive infrared spectrophotometer. Blanks and standards were run on a daily basis. All samples were analyzed in duplicate and averaged. Periodically samples were combusted at >800°C in a high vacuum, Craig-type combustion system as a check on the combustion efficiency of the Leco system.

Carbonate Carbon

Carbonate carbon was determined for the same freeze-dried, homogenized sediment samples that were used for organic carbon and hydrocarbon determinations. Carbonate carbon in Cruise I samples was determined by difference between total carbon and carbonate-free (organic) carbon, using the Leco WR-12 Total Carbon System. For samples from Cruise II, carbonate carbon was determined directly by acidification in a carrier stream, followed by infrared detection.

Carbon Isotope Analyses

Carbon isotope analyses were performed on sediments and selected organisms to determine their food source. Stable carbon isotopes have been shown to be useful in delineating the flow of carbon through ecosystems since there is considerable evidence for minimal carbon isotopic fractionation along marine food chains (Parker 1964, Degens et al. 1968, DeNiro and Epstein 1978). Plants preferentially assimilate ^{12}C over ^{13}C during photosynthesis, and the degree of ^{13}C fractionation in plants is dependent on the biochemical pathway used for carbon fixation. Photosynthetically derived carbon from marine algae generally have carbon isotopic values ranging from -19 to -21 ppt. Carbon from terrestrial sources is generally at least 7 ppt lighter (more negative) due to the uptake of CO_2 as opposed to bicarbonate in the sea. However, there are other pathways that can contribute to variations in the organic carbon isotopic content of terrestrial plants.

Organisms that feed on photosynthetically derived carbon from marine algae have carbon isotopic values in the same range as the plankton (-19 to -21 ppt). However, tissue from mussels recovered at the Pacific vents have delta ^{13}C values near -33 ppt (Rau 1981, Rau and Hedges 1979, Williams et al. 1981). The vent communities of the Pacific are based on chemautotrophic bacteria that gain energy from the oxidation of hydrogen sulfide (Karl et al. 1980). In turn, the associated filter feeding organisms feeding on these isotopically light bacteria have similar isotopic values.

Stable carbon isotopes (delta ^{13}C values) were determined on freeze-dried sediment organic carbon and tissue samples. The stable carbon isotopic CO_2 composition derived from combustion of the organic matter was determined on a Nuclide Corporation six inch, 60° sector, isotope ratio mass spectrometer. The carbon isotope values are reported as per mil deviations from the Pee Dee Belemnite (PDB) standard:

delta ^{13}C = [($^{13}C/^{12}C$) sample - ($^{13}C/^{12}C$) std/($^{13}C/^{12}C$) std] x 1000

High Molecular Weight Hydrocarbons

This study involved the measurement of high molecular weight (HMW) hydrocarbons in megafauna (fishes and invertebrates) and sediments in samples collected on the Gulf of Mexico slope. Sediment samples were screened for aromatic hydrocarbon contamination using total scanning fluorescence, but primary detection and quantification of petroleum contamination was based on high resolution capillary gas chromatography and GC/MS/DS analysis. The purpose of the HWM hydrocarbon analyses were:

1. To determine the suite of HMW hydrocarbons present and their concentrations;
2. To determine probable sources of the HMW hydrocarbons as either thermogenic (from natural seepage or anthropogenic sources) or biogenic;
3. To determine the relationship between HMW hydrocarbons and trophic levels;
4. To establish the extent of contamination with respect to distance from shore and/or offshore oil/gas production;
5. To determine the relationship, if any, between hydrocarbon chemistry, water depth, major current systems, and sediment physical characteristics; and
6. To compare the findings to known values for shallow water habitats in the Gulf of Mexico and subtropical U.S. Atlantic waters.

Protocols for analyzing both the sediment and benthic organisms were very similar (Figs. 2-4 and 2-5). To avoid repetition, HMW hydrocarbon methods for sediments are described below in detail, noting the differences in analytical techniques between methods for sediments and organisms.

Sediment Hydrocarbon Analyses. A three-tiered sediment hydrocarbon analysis program was implemented. First, extracts of surficial sediments

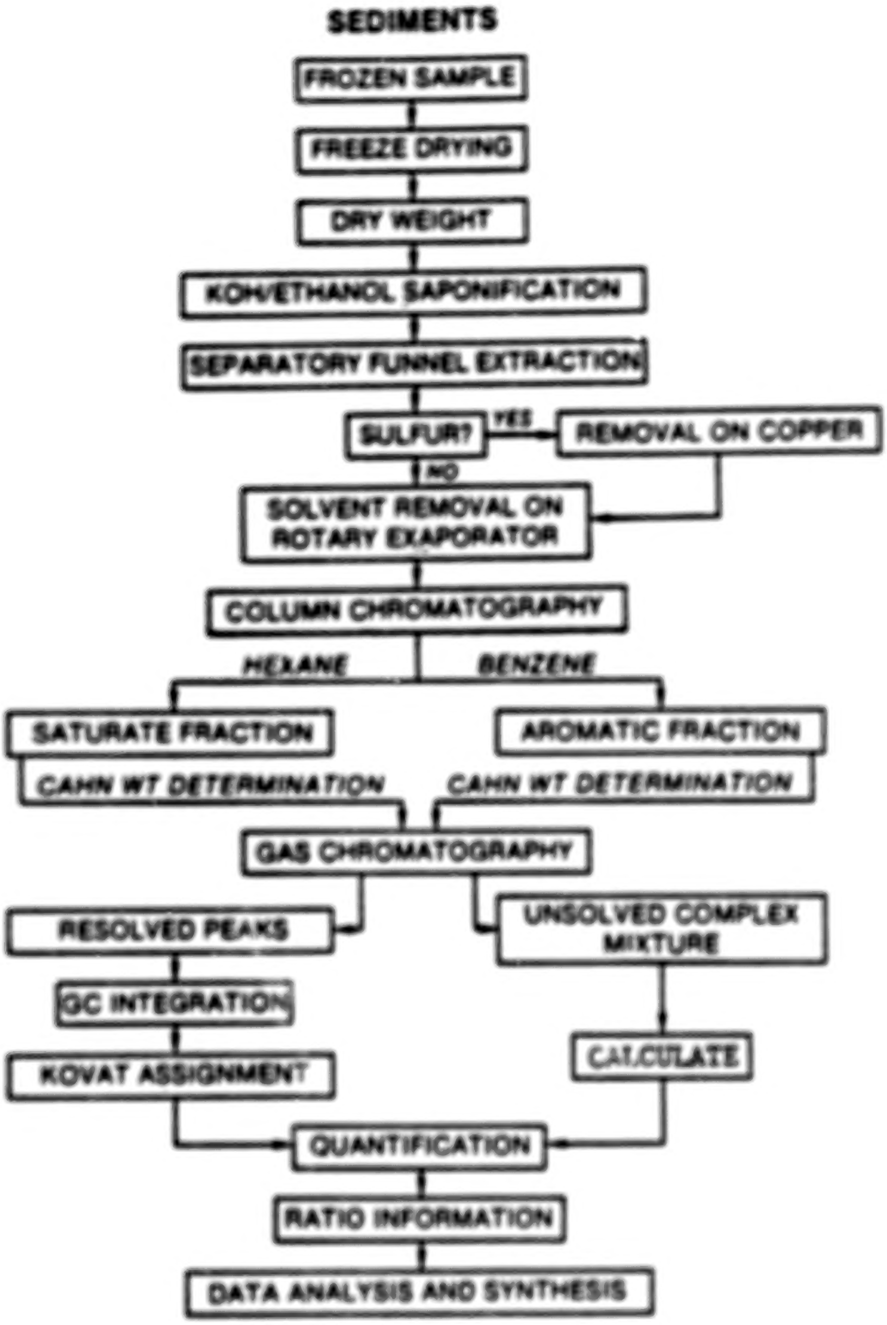

Figure 2-4. Sediment hydrocarbons analytical scheme.

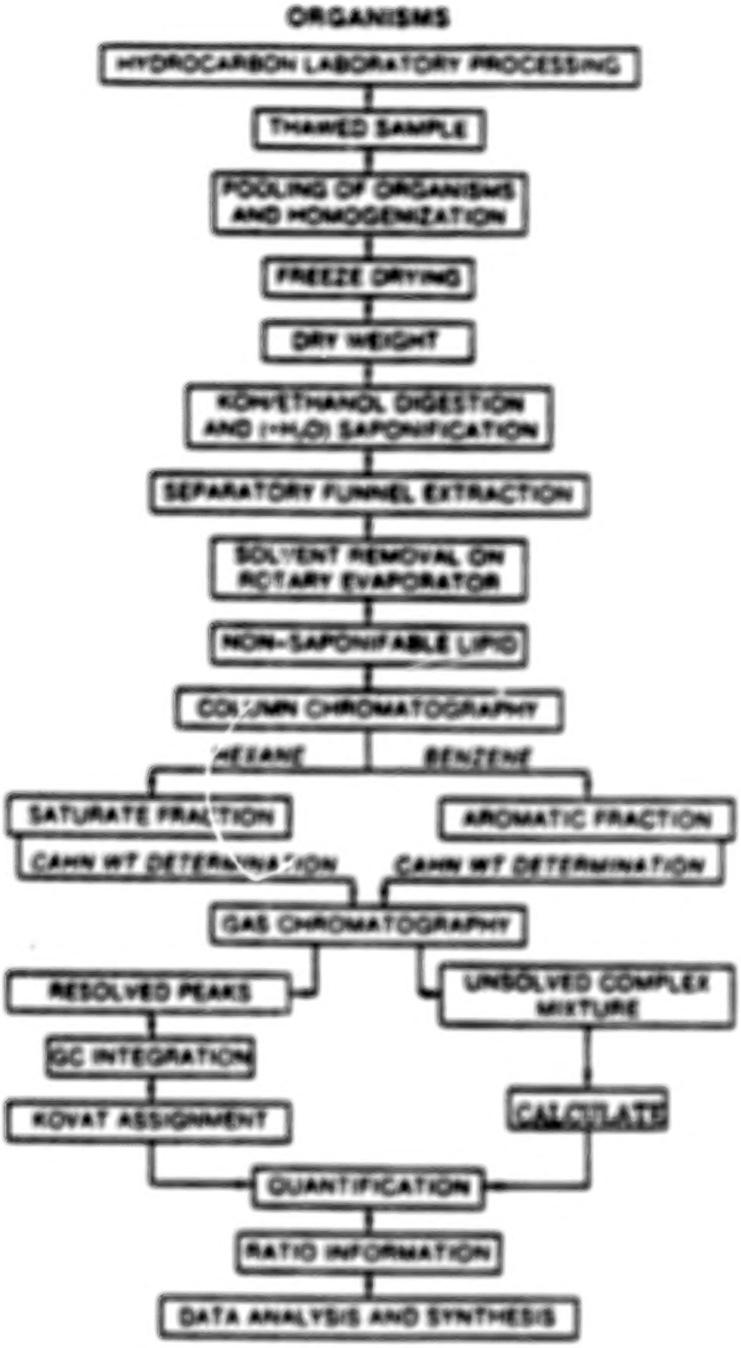

Figure 2-5. Hydrocarbon analysis scheme for organisms.

from each box core were analyzed by total scanning fluorescence to determine the presence or absence of aromatic hydrocarbons. Second, detailed saturate and aromatic capillary gas chromatography was performed on individual and/or pooled samples from each station. Third, selected samples were analyzed by gas chromatography/mass spectrometry (GC/MS) for compound identification and structure confirmation.

Sediment samples were obtained from box cores in a clean environment on board ship. A clean steel tube was used to subsample the upper 5-cm of the sediment. Samples were stored in jars that were solvent-washed and combusted at 450°C. The jars were sealed with teflon-lined caps, labeled, and stored frozen.

The establishment and maintenance of adequate procedural blanks is imperative in trace level hydrocarbon analysis. A quality control and quality assurance program was strictly followed. Precleaning of all equipment included extensive washings with Micro cleaning solution and rinsing with distilled water, acetone, and methylene chloride. All solvents were triple glass-distilled, nanograde purity (Burdick and Jackson, Inc.) or its equivalent. Final rinses were evaluated by gravimetry, gas chromatography and gas chromatography/mass spectrometry. Large volumes (one liter) of solvent were routinely evaporated and tested in a similar manner. When possible all equipment (i.e., glassware) was combusted at 450°C overnight, after the cleaning procedure is completed. Blanks were maintained at negligible levels for all parameters monitored.

Total scanning fluorescence--determination of trace levels of many organic species was possible using fluorescent measurements. Fluorometry is inherently selective, and generally at least ten times more sensitive than other absorption methods. Fluorescence methods are particularly useful for the detection and measurement of complex organic compounds containing one or more aromatic functional groups. All oils contain significant amounts of aromatics with one to four (or more) aromatic rings and their alkylated analogs. The aromatic composition of an oil provides a distinctive "fingerprint", and this fingerprint when used in conjunction with other analyses can provide significant typing information.

Fixed-wavelength and synchronous scanning fluorescence suffer from non-selectivity, and are generally ineffective in structural elucidation information for the next and more detailed characterization of the polynuclear aromatic hydrocarbons.

Fixed-wavelength fluorescence measurements were used to select a sample dilution where quenching was insignificant. Next, total scanning fluorescence measurements were performed on each sample, using a Perkin-Elmer Model 3500 or 3600 Data Station equipped with dual 5-1/4" floppy disk drives, controlling an automated 650-40 UV-spectrofluorometer. Three complete systems were in operation. The extracts were scanned to acquire data on three-dimensional fluorescence spectra of emission wavelength, excitation wavelength, and intensity. Using custom software, data acquisiton time was shortened to 30 min, with a wavelength resolution of 5 nm for the emission spectrum.

The emission spectrum was obtained by scanning the emission monochromator at a fixed excitation wavelength. The excitation spectrum was acquired by monitoring a fixed emission wavelength while scanning te excitation monochromator. The total fluorescence excitation-emission wavelength array was filled for each sample by sequential stepping of the excitation monochromator over the wavelength rang of interest, and scanning with the emission monochromator.

The data were stored in active memory. Standard wavelength intervals were 200-600 nm for both excitation and emission. Intensity data were acquired during each emission scan at preset wavelength intervals. Programming flexibility permitted acquisition speeds of from 60 to 450 nm/min on each monochromator. Up to 2500 discrete intensity values were acquired per spectrum, with a 1 nm resolution at slower scan speeds. After acquisition, the data were permanently stored on 5-1/4" diskette. The data were then transformed via a three-dimensional conversion routine, and a spectral plot generated with a standard graphics package on a CRT. The output was hard-copied on a graphics printer/plotter.

Gas chromatography/mass spectrometry--Sediment samples for fused silica capillary chromatography were freeze-dried before extraction to minimize sale entrainment into the extracts. Sample handling was kept to a minimum to avoid contamination of the samples. After freeze-drying, a sediment dry weight was obtained. The freeze-dried sample (50 g dry weight) was placed in a round bottom flask (500 ml), with standard taper (particularly for mixtures). Despite the ability to select both the excitation and emission wavelengths, the conventional luminescence methods have limited applicability since most spectra of complex mixtures often cannot be satisfactorily resolved. To overcome these problems, Texas A&M University developed a software package and methodology for three-dimensional total scanning (excitation-emission spectra) of fluorescence. The method is in routine use in the A&M laboratory, as well as those of a number of oil companies to analyze the extracts of surficial sediments, source rocks, and oils. This fluorescent method can differentiate gas-prone provinces with condensate aromatic signatures from oil-prone areas with oil signatures, and has been used by Brooks et al. (1983), Kennicutt et al. (1983), and Kennicutt and Brooks (1983) to estimate and type hydrocarbon concentrations in sediments and oils.

Approximately 20 g of sediment was required for total scanning fluorescence. A subsample was lyophilized, ground to a uniform size with a mortal and pestle, and Soxhlet-extracted for 12 hours in a 100% hexane solvent system. All glassware and aluminum thimble were precleaned with Micro cleaning solution, washed with nanograde solvents, and combusted at 500°C for at least four hours. The extracts were concentrated in a Buchli Rotovapor R to a volume of about five ml. Care was exercised at all time to ensure that the extract was not brought to complete dryness, in order not to volatilize the lighter sample components. The volume of the extract was raised to seven ml with hexane, and the extract was stored at 4°C in the dark until further analysis. A total system blank was run routinely for every set of samples, processed and checked by both fluorescence and gas chromatography to ensure acceptable blank levels.

The first level of fluorescence was similar to that of Hargrave and Philips (1975). Analyses were performed with a Perkin-Elmer 650-40 spectrofluorometer. Emission at 370 nm (excitation 265 nm) was used as the primary parameter to determine the presence or absence of petroleum-derived aromatic hydrocarbons. Fluorescence in this spectral region is primarily produced by aromatic hydrocarbons with three or more rings and provides the greatest sensitivity for the method. Samples which exhibit significant fluorescence at the original dilution can be further diluted until a proportional decrease in the emission spectrum indicates that quenching is insignificant. This level of characterization also provided ground glass neck, and mixed with 95% ethanol (150 ml), 50 ml of hexane, several glass beads or boiling chips, and KOH (10 g). The mixture was refluxed at 80°C for four hours.

Following the KOH/ethanol reflux, the digested material was transferred to a Teflon-stoppered separator funnel (one liter) using distilled H_2O (80 ml) and two portions (50 ml each) of hexane. The mixture was shaken by hand for five minutes to allow equilibration, and the solvent and aqueous phases were allowed to separate. Additional hexane was added if the two phases did not separate. The two phases were drained into separate flasks and the aqueous phase was returned to the separatory funnel using a hexane (50 ml) wash. The extraction and separation was repeated three times.

The combined hexane extracts are washed (minimum three times) with aliquots (500 ml each) of distilled H_2O to remove solids and residual alcohol. A saturated salt solution is often used to break the emulsion. To remove any residual water from the hexane extract, anhydrous Na_2SO_4 (2-3 g) is added. Copper turnings are added to the flask and the extract is refluxed for one hour to remove sulfur. The extracts are then roto-evaporated to near dryness and transferred to clean vials with methylene chloride. At all times care is exercised to ensure that the extract does not go to complete dryness to prevent loss of the more volatile components.

The extracts were fractioned into saturate and aromatics/esters fractions on alumina/silica gel columns. The silica gel was activated at 150°C for 16 hours and the alumina was activated at 350°C for 12 hours. The alumina and silica gel were then deactivated with 5% water. Deactivated packings were prepared immediately prior to their use. Ten grams of alumina and 10 g silica gel were hexane slurried individually over a plug of glass wool. The columns were cleaned with 100 ml of hexane which was then discarded.

The sample extract was dissolved in approximately one ml of hexane and applied to the surface of the column. A hexane (100 ml) and a benzene:hexane (100 ml, 50:50) fraction was then eluted. Optimum liquid chromatographic conditions and recoveries were tested using authentic standards. After collection each fraction was roto-evaporated, transferred to vials, and dried. The hexane fraction weight was obtained by dissolving the sample in 100 microliters of methylene chloride from which a 20 microliter aliquot was withdrawn and applied to a pre-weighed filter pad. The solvent evaporated and the aliquot was weighed to a tenth of a microgram.

The benzene:hexane fraction was further purified using a Sephadex LH-20 column (25-100 μ mesh). The Sephadex was slurried in the eluting solvent (cyclohexane:methanol:dichloromethane; 6:4:3), allowed to swell overnight, and slurry-packed in a glass, teflon-stoppered column. Each column was calibrated with authentic aromatic standards to determine the fraction to be collected. The column was pre-rinsed with 200 ml of the eluting solvent, then the sample, dissolved in the eluting solvent, was applied to the top of the column. The first 40 ml of the eluant was discarded while the next 100 ml was collected. This fraction was roto-evaporated, transferred to a vial, and weighed as for the hexane fraction.

Each sample was spiked with a known amount of several internal standards to correct for variability in recoveries and extraction efficiencies. Several compounds of similar structure but not naturally occurring were added for both aliphatic (i.e., 1-chlorooctadecane, polyolefins, or branched alkanes) and aromatic (i.e., hexamethylbenzene, branched aromatics, etc.) analyses. The concentrations of the internal standards were in the same range expected for naturally occurring compounds. The compounds chosen must be sufficiently resolved from all sample components. Authentic standards have shown that this analytical procedure provides the desired results.

The aliphatic and aromatic fractions from the columns were quantified by fused silica capillary gas chromatography. Hewlett-Packard gas chromatographs (Model 5880) were utilized in a spitless capillary mode. Fused silica capillary columns coated with a bonded phase (BP1/QC2; SGE, Ltd.) were used to attain separation of the extract components. Baseline separation of n-C_{17} and pristane and n-C_{18} and phytane was maintained at all times to insure proper resolution. The columns were 50 m long with an inside diameter of 0.25 mm.

Helium gas was added as a makeup gas between the capillary column and the flame ionization detector, in order to obtain the maximum sensitivity of the detector. The injection port was operated at 300°C and the detector at 350°C. Typical instrumental parameters are shown below:

PARAMETER	SETTING
Initial temperature	80°C
Initial hold	0 min
Rate	6°C/min
Final temperature	300°C
Final hold	20 min
Injection port temperature	300°C
FID temperature	350°C
Chart speed	0.50 cm/sec

Gas chromatograms were quantified with authentic standards. A combination of commercially available quantitative standards and standards prepared in the A&M laboratory were used. Sample peaks were identified by comparison of retention times with standards. All peaks were assigned a Kovats Index based on the retention times of a 20-component hydrocarbon standard containing normal alkanes from C_{13} to C_{34}. The alkanes, by definition, were assigned a Kovats Index equal to 100 times the number of carbon atoms they contain (i.e., n-C_{14} K.I. = 1400). The standard was then used to calculate Kovats Indices for other compounds based on interpolation between normal alkanes. All significant peaks in a sample were assigned a Kovats Index. Kovats Indices compensated for daily variations in operating conditions and allowed the direct comparison of data from different runs.

The Hewlett-Packard gas chromatographs were linked with an HP 1000 data system used for laboratory automation and manipulation of data. Existing analysis packages had the capacity to calculate response factors, which were a measure of the response of the detector versus the area of the peak. From the daily quantitative standard the gas chromatograph was calibrated in an external standard mode. The retention time and amount of each standard peak was used to calculate response factors for the standard compounds, and this information was stored on tape and/or hard disk. The output included the response, the retention time, the Kovats Index and the calculated concentration. The response factor was also used to determine the concentrations of peaks that do not correspond to components in the standard. Every attempt was made to obtain authentic standards for all significant sample components. The unresolved complex mixture concentrations were calculated based on average n-alkane response over the volatility range covered.

At least 10% of all samples were analyzed by gas chromatography/mass spectrometry (GC/MS) to confirm the identity of the sample components and to identify when possible any unknown compounds. The gas chromatography/mass spectrometry was conducted with a Hewlett Packard 5996 GC/MS system coupled with a Hewlett Packard 1000 data system. Gas chromatographic columns and conditions were identical to the quantitative GC analyses. A splitless injection technique was used. The total column effluent was routed directly into the ion source of the mass spectrometer. Standard n-alkanes were run daily to confirm Kovats Indices. Typical operating conditions for the mass spectrometer are listed below:

FACTOR	CONDITION
1. Source temperature	300°C
2. Detector gain	2 x 10^6
3. Source conditions	
a. Drawout lens	10 volts
b. Repeller	22 volts
c. Ion focus lens	30 volts
d. Electron energy	70 eV
e. X-ray	3
f. Electron focus	0
g. Scanning rate	215 amu/sec
h. Electron emission	160 uA
i. Target	160 uA
4. Calibration with perfluorotributylamine (PFTBA)	

The mass spectrometer was repetitively scanned from m/z 33 to 400 every 2.1 sec. Ionization was accomplished using 70 eV electrons. The ion source temperature was maintained at 300°C. All substantial peaks had their fragmentation patterns hard copied and all data stored on tape for future reference. Spectral interpretations were aided by computer library searches (in-house and NIH/EPA/CIS), the eight-peak index, reference texts, and the periodical literature.

2.3.2.2 Biological Samples from Box Cores

Meiofauna

Meiofaunal samples were gently rinsed through a 300 micron sieve to remove larger organisms, and then through a 63 micron sieve. The material on the 63 micron sieve was then placed carefully--small amounts at a time--into a sorting dish partially filled with water. Individuals were sorted by major taxon under a dissecting scope, using an Irwin loop to transfer specimens to vials containing 70% ethanol. The vials were uniquely labeled according to collection date, location, replicate number etc., taxon, and the number of individuals contained in the vial. Biomass was estimated based upon published literature values for the size ranges of organisms in the samples (Faubel 1982, Rowe et al. 1974).

Macrofauna

Macrofaunal samples were gently rinsed with water to remove preservative, placed in a Petri dish--small amounts at a time--and examined under a dissecting microscope. Specimens were removed and sorted by major taxonomic group into labeled vials containing 70% ethanol. Wet-weight biomass was estimated for each taxonomic group based upon values reported in various published literature (Faubel 1982, Rowe et al. 1974)

All major taxonomic groups except Nematoda, Harpacticoida, Aplacophora, Scyphozoa (strobilas), Priapulida, and Acarina were given either to in-house or consulting taxonomic specialists for identificaion to the species level, if possible. The following is a list of taxonomic groups and the specialists responsible for identification of specimens within each group:

TAXONOMIC GROUP	SPECIALIST(S)
Porifera	Shirley Pomponi (Consultant), Daniel La Chance (Consultant)
Actiniaria	Daphne Dunn Fautin (California Academy of Sciences)
Alcyonaria	Jennifer Lowry (Consultant), Steven A. Viada (LGL)
Scleractinia	Stephen Cairns (Smithsonian Institution), Steven A. Viada
Hydrozoa	Dale Calder (Royal Ontario Museum)
Nemertea	Judy Wern (Texas A&M University)
Oligochaeta	Christer Erseus (University of Goteborg)
Polychaeta	G. Fain Hubbard (LGL), Paul Wolf & Linda Sierte (Barry A. Vittor & Assoc, Inc.)
Bivalvia	Frank Rokop (Scripps Institute of Oceanography), Thomas R. Waller (Smithsonian Institution)
Cephalopoda	Michael Sweeney (Smithsonian Institution)
Gastropoda	Philippe Bouchet (Museum National d'Historie Naturelle)
Scaphopoda	J.N. Kraeuter (Baltimore Gas & Electric)
Pycnogonida	C. Allan Child (Smithsonian Institution)
Pogonophora	Meredith Jones (Smithsonian Institution)
Amphipoda	Larry McKinney (Texas Parks & Wildlife)
Cirripedia	Henry Spivey (Florida State University)
Cumacea	Norman Jones (University of Liverpool)
Isopoda	George Wilson (Consultant)
Ostracoda	Louis Kornicker (Smithsonian Institution)
Stomatopoda	David Camp (Florida Dept. of Natural Resources)
Tanaidacea	Richard Heard (Gulf Coast Research Lab)
Decapoda	Linda Pequegnat (Consultant), Willis Pequegnat (Consultant), Patsy McLaughlin (Florida International University)
Asteroidea	David Pawson (Smithsonian Institution)
Crinoidea	Charles Messing (University of Miami)
Echinoidea	David Pawson (Smithsonian Institution)
Holothuroidea	Robert Carney (Louisiana State University)

Ophiuroidea	Gordon Hendler (Los Angeles County Museum of Natural History
Brachiopoda	G. Arthur Cooper (Smithsonian Institution)
Bryozoa	A.J.J. Leuterman (Dresser Industries)
Sipunculida	Mary Rice (Smithsonian Institution)
Tunicata	Claude & Francoise Monniot (Museum National d'Historie Naturelle)
Fishes	Charlie Chandler (LGL), Eddie Matheson Texas A&M University), John McEachran (Texas A&M University)

2.3.2.3 Trawl Samples (Megafauna)

Identification and Enumeration

Megafauna from the trawl samples were removed from the storage containers, rinsed to remove formalin, sorted, identified, and counted to major taxonomic group. Specimens were examined by the taxonomists listed above (2.3.2.2, Biological Samples from Box Cores, Macrofauna), who identified most to the species level.

Size and Reproductive Condition

Fish and selected decapod species were weighed to the nearest 0.1 g (drained wet weight) and measured using the standard method for the taxonomic group in question. Where possible, sex and state of maturity were determined externally or internally if the specimen was examined for gut contents.

Gut Contents

Guts of selected representatives of common fishes were dissected and examined for assessment of food habits. Stomach contents were examined for the following parameters:

1. Percentage fullness, by volume;
2. Percentage composition by food item group, by volume;
3. Wet weight of each food item group; and
4. Number of individuals in each food item group.

High Molecular Weight Hydrocarbons

As mentioned in Section 2.3.2.1 (Sediment Samples from Box Cores), the organism hydrocarbon analytical scheme was very similar to the one used for sediments (Fig. 2-5). No fluorescence screening was performed. Since organisms do not generally contain large amounts of sulfur, desulfurization with copper was not necessaary. Three tissue types (liver, gonad, and muscle) were analyzed in fish specimens. Only muscle tissue was analyzed in other benthic fauna (shrimp, crabs, etc.). Organisms are frozen at -20°C on board ship. Dissection was performed in a shore-based, clean laboratory. All utensils were pre-cleaned using procedures described in the sediment section. The target sample weight was 15 g wet weight. The method of digestion of tissues was identical to that used for sediment. The methods used in column separation, gas chromatography (GC), and gas chromatography/mass spectrometry (GC/MS) were also identical to those used in the sediment analytical scheme.

Carbon Isotopes

Carbon isotope methods are described in Section 2.3.2.1.

2.3.2.4 Benthic Photography

A procedure for detailed evaluation of benthic photographs was developed specifically for this project. Benthic photography samples obtained from photographic transects were processed on a digitizing pad driven by a microcomputer. The sizes of objects seen in the photographs were calculated from their distance from the camera (i.e. camera altitude, recorded in the corner of each shot) and the acceptance angles of the camera lens. Knowledge of the scale of the photographs made it possible to calculate the area shown in each photograph, and to measure the sizes of various features and biota. Each photo thus served as a quantitative quadrat sample of the survey site (Grassle et al. 1975).

The acceptance angles of the lenses were 35° (length) and 48.5° (width). The dimensions of one half of a quadrat can be calculated trigonometrically as:

1/2 quadrat length = altitude x tan 17.5°
1/2 quadrat width = altitude x tan 24.25°

The area included in a photograph is twice the product of these two numbers.

Processed film was projected through a modified bulk film projector and a front-silvered mirror mounted at a 45° angle (Fig. 2-6). The mirror reflected the photographic image onto a Houston Instruments Hi-Pad DT-11VA digitizing pad connected to an Apple IIe microcomputer. The software for the computer was developed by LGL.

A subsample of either 100 frames (Cruise II) or 200 frames (Cruises III-IV) was selected from an entire roll from each station, using a systematic sampling technique described by Cochran (1977). From each frame, the digitizer operator first recorded the following on microdiskette:

1. Cruise number;
2. Date (day, month, year);
3. Station number;
4. Time of day of exposure (hour, minute, second);
5. Bedform type (deviations from a flat bed);
6. Sediment color;
7. Bottom type;
8. Camera altitude; and
9. Bottom depth.

The digitizer's cursor was then used to count and measure the subjects in the photograph. The operator had the ability to select any of three means to measure objects seen, depending on his judgement of the best representation of the object. He could determine whether the object

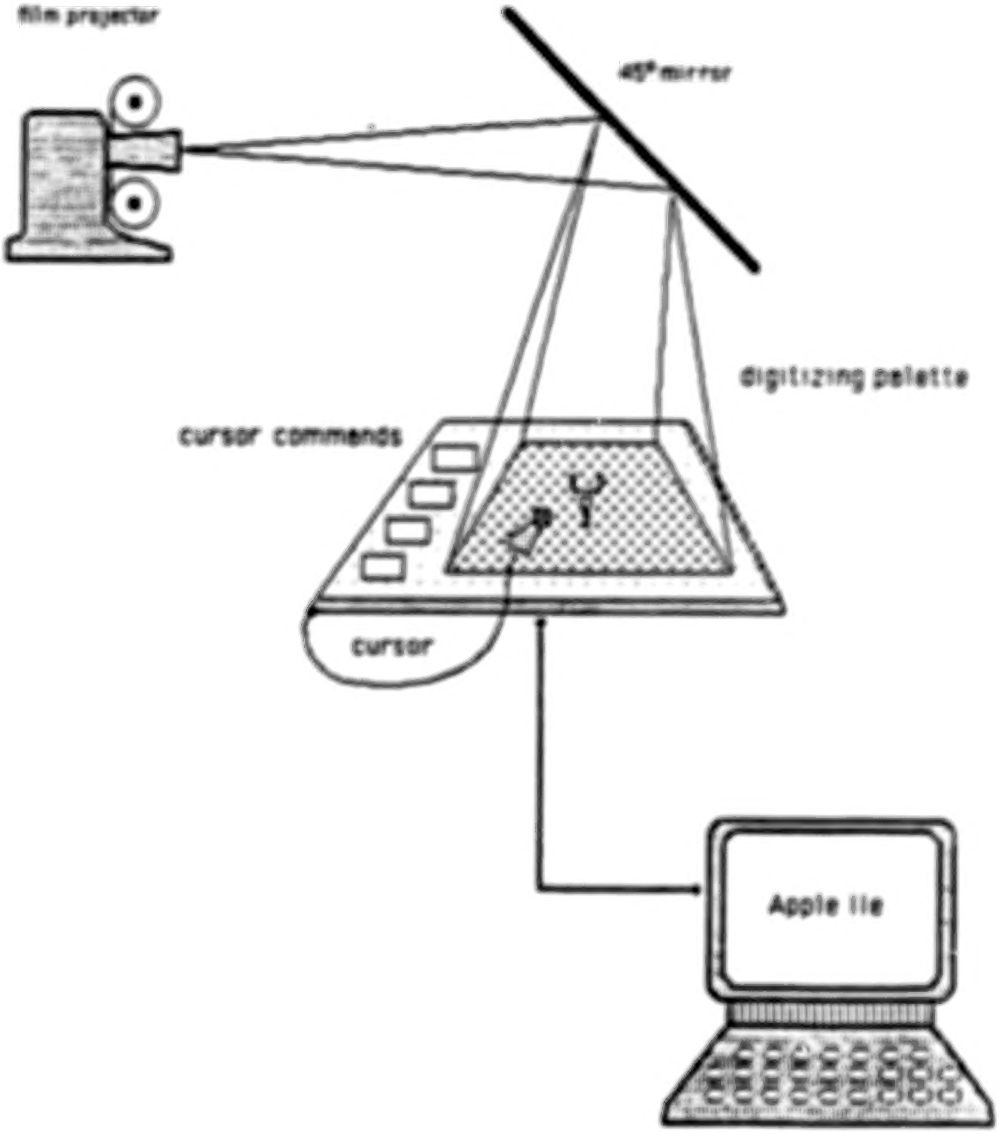

Figure 2-6. Schematic representation of digitizing apparatus used for processing benthic photographs.

was most appropriate to measure as a point, a straight line, or a closed figure. Each procedure utilized a different software routine, which could be activated with a cursor command.

Data records from the digitizer were transmitted from the Apple IIe to a database. The custom software used the scale of the photographs to convert the digitized images and counts into estimates of lengths, areas, and densities. Types of data records or categories resulting from photographs included the following:

1. Numbers of benthic invertebrates, identified to the lowest possible taxon, encoded as points or lines representing appropriate lengths or widths for each taxon;
2. Numbers of fish, identified to the lowest possible taxon, encoded as points or lines representing total length;
3. Man-made artifacts such as cans, bottles, plastic, etc., encoded as points, lines, or areas;
4. Terrigenous or near-shore materials such as sea grass blades, encoded as points, lines, or areas;
5. Consolidated materials such as hard rocks, siltstone, etc., generally encoded as a closed figure or area; and
6. Lebensspuren or traces in sediment left by living organisms, encoded as lines or areas if possible, but in some instances as points (and then converted to areas represented by the minimum resolution of the digitizer).

2.3.2.5 Quality Assurance and Quality Control (QA/QC)

Biological Samples

The biologists who were involved in the sorting and identification to major taxonomic groups were periodically checked and instructed to maintain the high level of efficiency needed for this project. Each sorter was given an indoctrination and training session to familiarize that person with the project's goal and objectives, and to teach him/her the details of the specific techniques he/she would be using for sample processing. Most sorters were biologists with bachelor's or master's degrees.

Macrofauna sorters were initially given close supervision and training while processing their first sets of samples. These "training" samples were rechecked by an experienced supervisor before a new sorter was allowed to proceed further. Additional instruction and training was given if necessary. If the sorter seemed unable to perform satisfactorily, he was not allowed to process any more samples. Once the laboratory supervisor was satisfied with the sorter's performance, he was placed in the routine schedule for sample workup.

After the training period, each sorter was periodically tested for sorting efficiency, proficiency in taxonomic identification, and ability to follow sample handling protocols such as chain-of-custody procedures and proper labeling techniques. The usual standard was to accept a sorter's past work if randomly-selected samples were sorted with at least 90% accuracy, i.e. at least 90% of the individuals in the samples were correctly identified. Counts of organisms in each vial were checked, and the sediment residue was also examined. If the work was judged inadequate, all samples previously handled by the sorter were re-worked. Continued poor performance resulted in the sorter's dismissal or transfer to other duties.

Upon arrival in the lab, samples were inventoried and organized prior to sorting. Samples were subsequently checked out individually on a "Sample Check-out Sheet" located in the storage area. The sheet required each sorter to record his initials, the sample number, station, replicate, and date checked out for sorting. After sorting, the date of completion was recorded on the Sample Check-out Sheet, and on a "Sample Disposition Status Sheet."

Sorted taxonomic groups were separated and inventoried by taxon, and sent to the appropriate taxonomic specialist(s) along with copies of the Sample Disposition Status Sheet, station data sheets, and work authorization forms. Samples were sent by Certified U.S. Mail, Return Receipt Requested. Taxonomic specialists were instructed to send identified material directly to the Smithsonian Institution, U.S. National Museum of Natural History, along with the proper labeling information.

Mis-sorted material was returned to LGL, and re-directed to the appropriate specialist.

As part of an ongoing effort to document the quality of samples collected, a study was conducted on box core macrofaunal samples, using the basic assumption that a "good" sample should have the same proportions of major taxa in both the box and the meiofaunal tubes from the same replicate. Meiofaunal tubes were more protected by the box core lid from washout, and were sieved under controlled laboratory conditions as opposed to field conditions. Paired samples (box and tubes) were thus analyzed for relative proportions of major taxa.

Following Hessler and Jumars (1974) and Jumars (1980), a Chi-squared test for proportions was used to evaluate significant departures from expectation. A field-assigned quality designation was indicated by 1, 2, or 3, representing low to high quality based on observations when the corers came on deck. Only seven of the 30 replicates tested were demonstrated to have lower quality (Fig. 2-7). In general, borderline samples were characteristically better than anticipated, based on field observations.

Hydrocarbons

Replicate analyses were performed on both a standard sediment and a standard fish muscle tissue sample. Results for alkane analysis are reported in Tables 2-1 through 2-5. Replicate gravimetric analyses were precise within 20 to 30% (± 1 sigma) at the ppm level (Table 2-1). Replicate analysis of individual n-alkanes varied from -5 to 50% (± 1 sigma) at the ppb concentrations in sediments depending on molecular weight (Tables 2-2 and 2-3). Comparison of two analysts processing the same sediment sample is illustrated in Table 2-4 (gravimetric analysis only). Recovery of surrogate standards was generally in the 80-90% range, with this percentage reaching a constant value at n-C_{19} (i.e., the lower molecular weight alkanes are lost in roto-evaporation, Table 2-5).

Each set of eight analyses contained six samples, one reagent blank, and one reagent blank plus the complete quantitative n-alkane and aromatic standard. All samples were spiked with an aliphatic and an aromatic

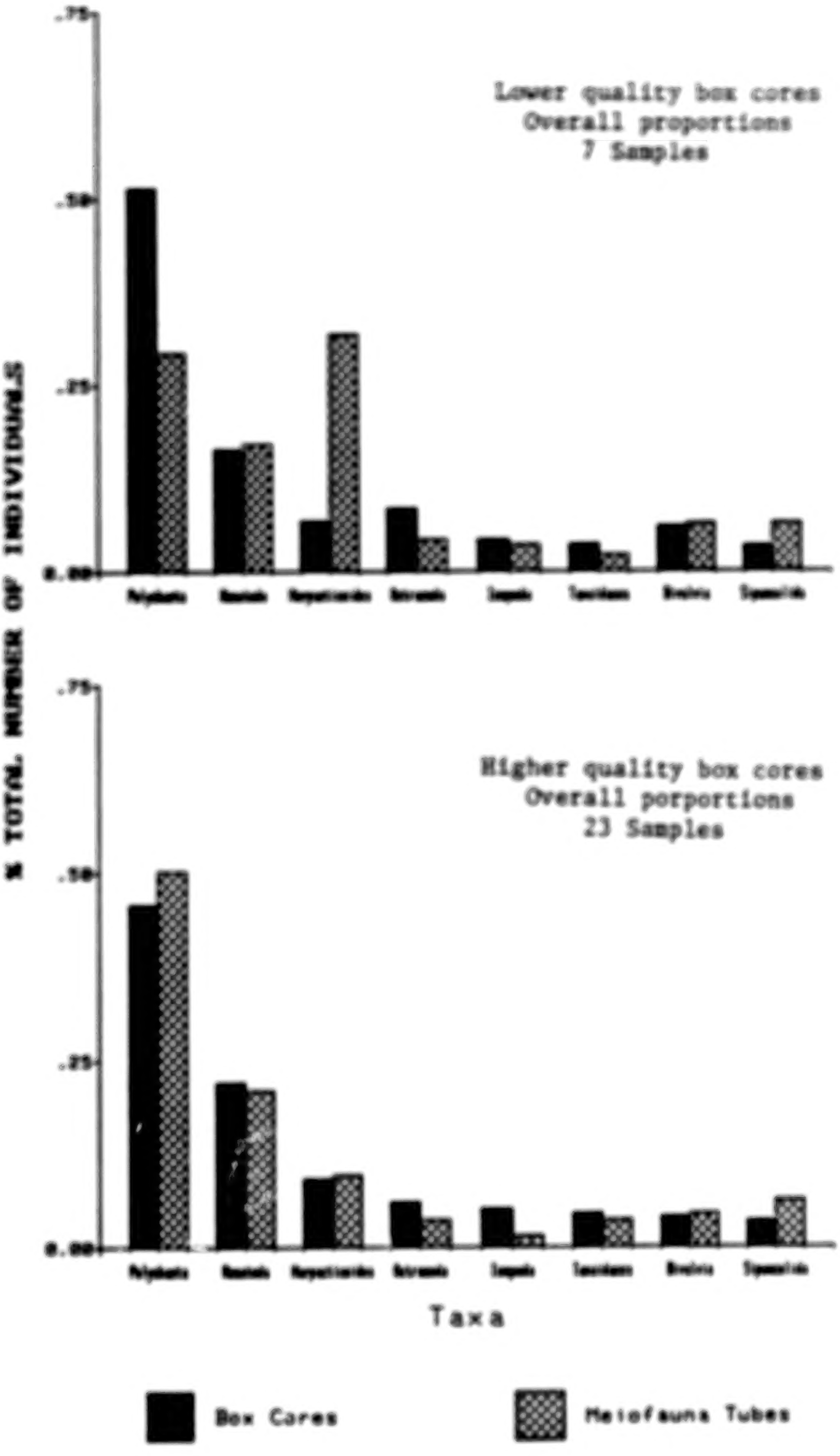

Figure 2-7. Proportion of macrofauna organisms in disturbed and undisturbed box core samples.

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Table 2-1. Summary of the precision of replicate gravametric analyses of digestion/fractionation (NMFS Analytical Scheme) and its comparison to Soxhlet extraction/fractionation (concentrations in ppm, µg/gm).

Sample	Repl. #	Digestion Extraction		Soxhlet Extraction	
Q.C. Miss. Delta Sediment					
Aliphatic Fractions	1	9.1			
(ppm)	2	8.9	Ave.= 10.3 (9.2)*	25.2	Ave.=31.8
	3	12.0	S.D.= 3.3 (1.4)*	33.0	S.D.= 5.3
	4	17.8*	C.V.= 32.1%(14.9)*	38.1	C.V.=16.8
	5	8.6		30.8	
	6	7.6		---	
	7	9.4		---	
	8	8.6		---	
Aromatic Fraction					
(ppm)	1	9.1		5.2	Ave.= 8.8
	2	6.3	Ave.= 6.7	7.7	S.D.= 3.4
	3	8.4	S.D.= 1.5	13.4	C.V.=39.0
	4	6.3	C.V.= 22.2%	8.9	
	5	5.7		---	
	6	4.5		---	
	7	7.4		---	
	8	6.2		---	
Whitefish Q.C. Tissue					
Aliphatic Fraction					
(ppm)	1	20.1	Ave.=29.4 (24.8)*	45.7	Ave.=48.0
	2	27.7	S.D.=10.7 (3.5)*	43.1	S.D.= 8.8
	3	27.3	C.V.=36.3%(14.2%)	41.0	C.V.=18.4%
	4	24.2		63.2	
	5	47.7*		46.8	
Aromatic Fraction					
(ppm)	1	20.6		66.2	Ave.=54.8
	2	14.0	Ave.= 20.1	38.7	S.D.=14.3
	3	19.4	S.D.= 4.5	60.2	C.V.=26.0%
	4	19.6	C.V.= 22.5%	40.3	
	5	26.7		68.4	

* Calculated excluding the one anomalously high concentration.

Table 2-2. Summary of MMS QC sediment digestion/extraction replicate gas chromatographic analyses (concentrations in ppb).

Carbon #	Replicate 1	2	3	4	5	6	Ave.	S.D.**	C.V.***
14	-	-	3.7	3.0	1.9	-	2.9	0.9	31.3
15	-	1.9	3.4	2.4	1.6	-	2.3	0.8	34.3
16	3.7	7.3	19.0	11.9	12.5	7.0	10.2	5.4	53.1
17	11.9	17.4	42.3*	21.8	18.0	16.0	17.0	3.6	21.0
Pristane	17.0	23.9	34.0	25.7	26.3	21.4	26.4	7.3	27.5
18	26.5	30.5	71.9*	40.7	34.8	35.6	33.6	5.4	16.0
Phytane	38.4	36.5	51.1	40.8	38.7	37.8	40.6	5.4	13.2
19	34.1	36.6	83.0*	48.8	39.0	41.9	40.1	5.7	14.1
20	32.5	33.2	74.4*	38.8	33.9	37.0	35.1	2.7	7.7
21	28.2	28.0	64.7*	30.7	28.4	31.5	29.4	1.6	5.5
22	28.4	27.3	58.6*	29.3	27.1	30.3	28.4	1.3	4.8
23	46.4	49.0	74.8*	45.9	45.8	49.2	47.3	1.7	3.6
24	38.4	36.7	56.2*	32.6	32.7	34.6	35.0	2.5	7.2
25	143.1*	108.4	111.4	105.2	100.9	96.9	104.6	5.8	5.5
26	56.9	53.4	68.5*	48.4	51.7	51.9	52.5	3.1	5.9
27	168.1	199.2	203.4	172.2	186.0	185.0	185.7	14.1	7.6
28	73.3	60.7	70.1	53.6	55.4	56.4	61.6	8.2	13.4
29	353.1	330.3	310.2	296.9	294.3	295.2	313.3	23.8	7.6
30	51.8*	40.8	43.7	32.0	35.5	30.1	36.4	5.6	15.8
31	195.3	194.7	189.5	175.8	175.5	186.2	186.2	9.9	5.3
32	6.2	7.2	6.6	6.1	6.9	6.5	6.6	0.4	6.3
Total Resolved Alkanes	1343.3	1323.3	1640.5*	1262.6	1256.9	1250.5	1287.2	42.8	3.3

* values excluded were more than 3σ from the average.

** S.D. = Standard deviation

*** C.V. = Coefficient of variation (S.D./$\bar{x}$ x 100)

Table 2-3. Summary of replicate digestion gas chromatographic analyses of QC whitefish tissue (concentrations in ppb).

	Replicate #							
Carbon #	1	2	3	4	5	Ave*	S.D.**	C.V.***
16	--	--	--	--	--			
17	18.7	60.8	54.2	40.0	40.0	48.7	10.5	21.5
Pristane	124.4	208.5	186.4	167.6	156.7	168.7	31.6	18.8
18	164.1	193.4	237.4	204.2	204.9	200.8	26.3	13.1
Phytane	200.9	198.5	250.1	226.6	227.7	220.8	21.4	9.7
19	193.8	384.3	517.0	463.2	482.5	461.7	56.2	12.2
20	426.4	362.3	491.7	444.2	470.7	439.1	49.6	11.3
21	191.3	154.7	223.9	196.9	221.3	197.6	28.0	14.2
22	103.6	88.6	115.6	115.3	121.3	108.9	13.0	12.0
23	39.7	26.5	58.6	48.4	65.1	47.7	13.7	28.7
Total Resolved Alkanes	1462.9	1677.6	2134.9	1906.4	1990.2	1834.4	265.7	14.5

* Ave. = Average Concentration

** S.D. = Standard Deviation

*** C.V. = Coefficient of Variation (S.D./$\bar{x}$ x 100)

Table 2-4. Comparison of the precision of digestion/extraction gravametric analysis between two different analysts (concentration in ppm, µg/gm).

Sample	Repl. #	Analyst #1	Analyst #2
Q.C. Miss. Delta Sediment Aliphatic Fraction	1	9.1	6.3
	2	8.9	12.6
	3	12.0	16.7
	4	17.8	7.1
	5	8.6	13.7
	6	7.6	13.3
	7	9.4	--
	8	8.6	--
		Ave.=10.3	Ave.=11.6
		S.D.= 3.3	S.D.= 4.1
		C.V.=32.1%	C.V.=35.0%
Aromatic Fraction	1	9.1	10.5
	2	6.3	6.1
	3	8.4	7.4
	4	6.3	11.3
	5	5.7	8.3
	6	4.5	7.3
	7	7.4	--
	8	6.2	--
		Ave.= 6.7	Ave.= 8.5
		S.D.= 1.5	S.D.= 2.0
		C.V.=22.2%	C.V.=26.6%

Table 2-5. Summary of accuracy experiments for selected n-alkanes (reported as percent recovery of individual compounds).

	Replicate # % Recovery				
Carbon#	1	2	3	4	Ave.
13	2.6	0.0	0.0	0.0	0.7
14	9.0	1.6	1.4	2.3	3.6
15	16.6	2.3	6.0	39.7	8.7
16	24.6	6.9	13.2	21.0	16.5
17	34.5	23.3	23.0	32.1	28.2
Pristane	42.7	27.7	29.4	36.1	34.0
18	65.4	71.0	52.7	59.5	62.2
Phytane	51.2	51.7	41.4	45.5	47.5
20	88.3	94.9	76.6	76.0	84.0
21	83.6	91.7	75.0	72.5	82.8
22	84.0	95.0	77.1	73.6	82.4
23	85.6	99.9	78.3	76.0	85.0
24	83.2	100.2	77.6	75.0	84.0
25	82.5	114.7	78.9	76.8	88.2

internal standard. All gas chromatographic calculations were corrected for internal standard recoveries but gravimetric data were not.

Diesel oil, lube oil, and bilge water were collected from the vessels used in sample collection. Examples are shown in Figure 2-8.

2.3.3 DATA MANAGEMENT AND STATISTICAL ANALYSES

The sequence of data management and analysis procedures used by LGL is shown in Fig. 2-9. Most of the project data comes to the data management group on coding forms which were designed by the data manager and key project personnel at the outset of the program before any data were collected. Field and laboratory data were coded onto these data forms by laboratory personnel and then processed by the procedure described below. Data received on magnetic tape from TAMU was transferred either to the Amdahl 470V/6 or to the UNIX, depending on where the analysis took place.

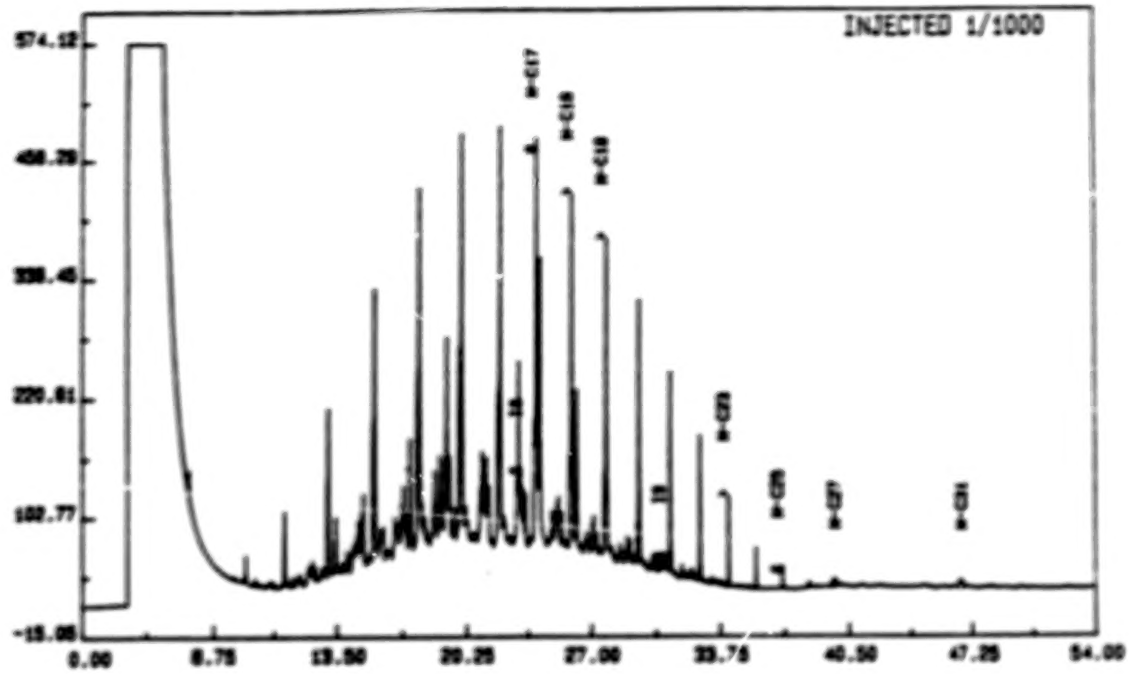
2.3.3.1 Data Entry, Verification, and Validation

Introduction

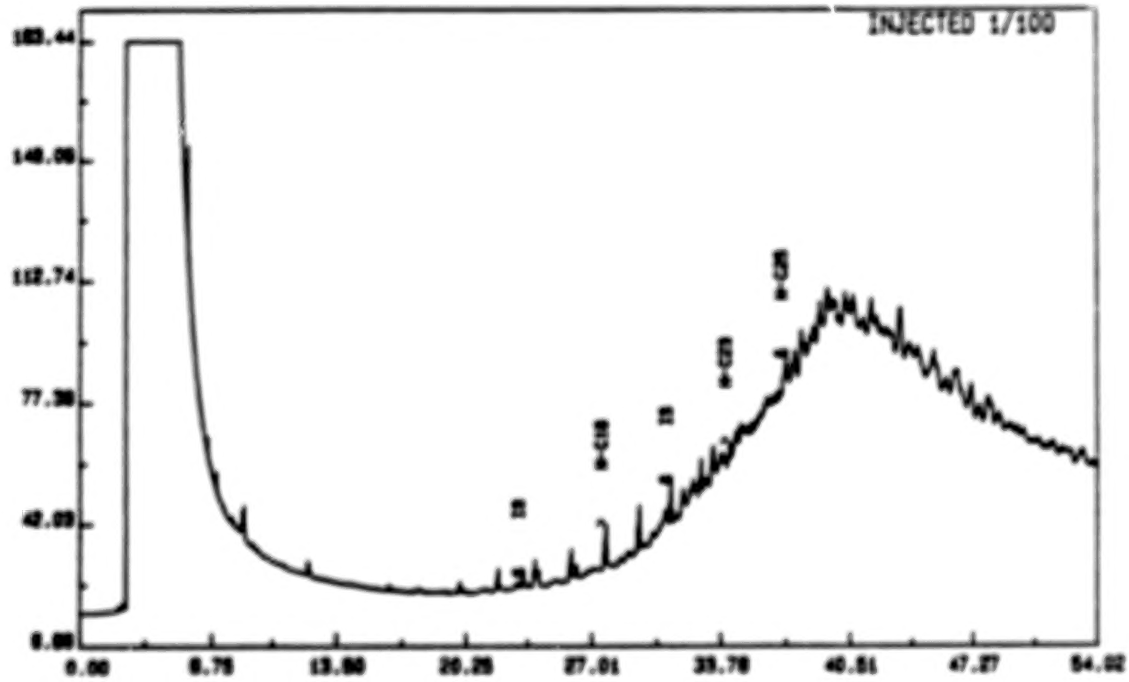
The process of data entry, verification and validation relies heavily on standard practices and experience. Various analytical determinations, simulations and actual implementation determine an appropriate "best" method for a given system and set of hardware. Since every data file is inherently unique, there is really no one best method. The following descriptions and comparisons/contrasts detail the standard methods used at LGL. These methods are the result of a six-year data management study during which various types and combinations of the methods for entry, verification and validation were tried, each with its own successes and failures.

Data Entry

The encoding of the data was based on the batch system. The encoding involved copying the field or lab information to a suitably-devised coding



Fuel Oil



Lube Oil

Figure 2-8. Example gas chromatograms of possible contaminants collected from sampling vessels.

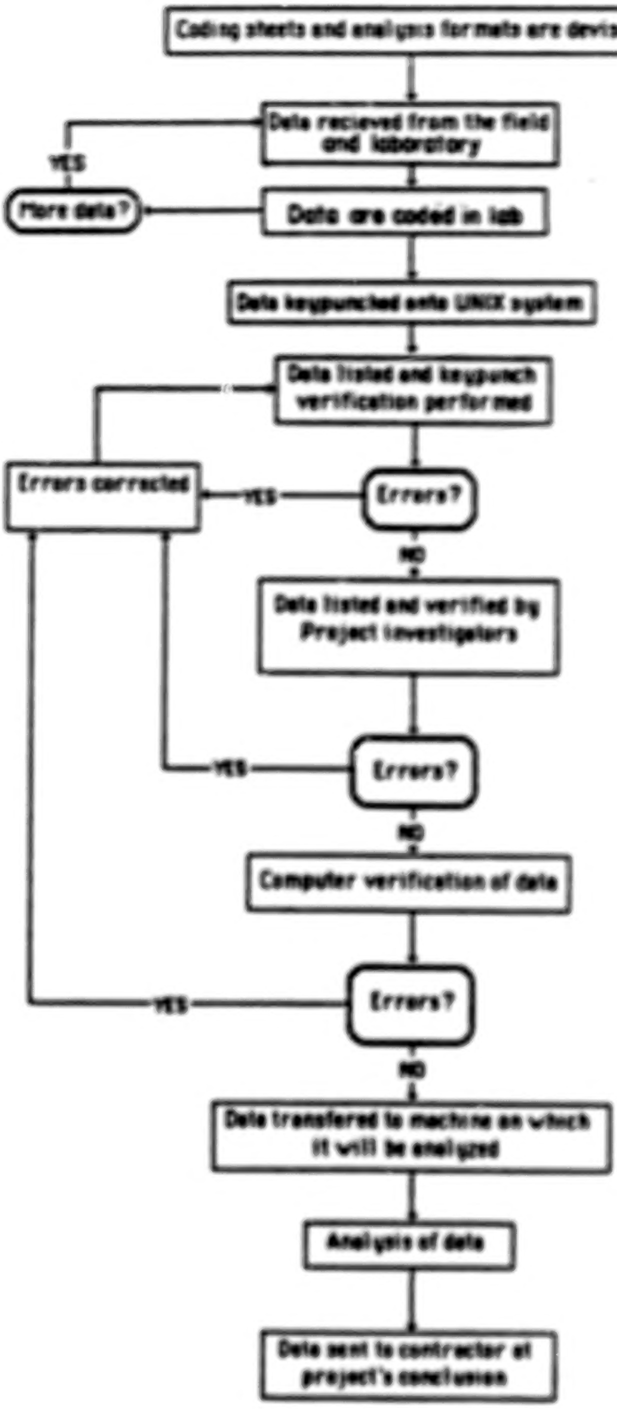

Coding sheets and analysis formats are devised
Data recieved from the field and laboratory
YES
More data?
Data are coded in lab
Data keypunched onto UNIX system
Data listed and keypunch verification performed
Errors corrected
YES
Errors?
NO
Data listed and verified by Project investigators
YES
Errors?
NO
Computer verification of data
YES
Errors?
NO
Data transfered to machine on which it will be analyzed
Analysis of data
Data sent to contractor at project's conclusion

Figure 2-9. Data flow sequence for Continental Slope Study.

form, and manual verification that the coded form matched the original form. Usually this was performed by two groups, one to encode and one to verify content. Once a batch was complete, it was given to the Data Manager for incorporation into the database via the data management cycle of entry, keypunch verification, Project Investigator validation/verification and computer validation. Once received by the Data Manager, a Summary Report Form (SRF) was started (and attached permanently to the batch) which detailed information such as:

1. Study name, data set identification, batch ID and encoder ID;
2. Date of receipt of coding forms by the Data Manager;
3. Date of keypunch entry and ID of keypuncher;
4. Total records entered for batch;
5. Date of keypunch verification
    a. whether or not errors were found,
    b. date of correction of error,
    c. date of verification of errors, and
    d. back to Step 5 until no more errors;
6. Date of Project Investigator validation/verification
    a. whether or not errors were found,
    b. date of correction of error,
    c. date of verification of errors, and
    d. back to Step 6 until no more errors;
7. Date of integration into database;
8. Date of archival; and
9. Additional notes/comments pertaining to batch or data set as a whole.

Once the Data Manager initiated the batch via this form, it was ready for entry by keypunch personnel using entry software on the LGL UNIX System V Operating System. A batch was entered by only one person in order to maintain strict control and traceability of the data. Once entered, the keypuncher dated and initialed the SRF, which was given to the Data Manager along with the batch coding forms. At this point, the Data

Manager verified dates, initials and locations of the batch, and produced a hard copy printout for verification.

Keypuncher Verification

Keypunch verification was performed by the keypuncher under the direction of the Data Manager. This method entailed the verification of the batch in a character-by-character, and line-by-line, comparison process of the hardcopy printout against the coding form. The coding form was used as the standard rather than the actual lab forms, since the process of keypunch verification is designed only for catching typographical errors, not validation errors which were caught using the original data forms. Since the batch was entered using field entry software, values which were constant for a specific field or fields needed to be checked only once since the field was static and therefore not subject to change.

Any errors found were noted on the hardcopy printout, dated, and initialed by the keypuncher who performed the verification. Also, the SRF was updated, indicating whether or not errors were found. The batch, printout and SRF were then turned over to the Data Manager, who performed any and all corrections, noting the date of correction on the printout where the errors were found. Once all noted errors had been corrected, the SRF was again updated to indicate this, a new hardcopy printout was obtained, and the Data Manager gave the batch, printout and SRF to another keypuncher who performed a verification of corrections. This cycle was continued until there were no more typographical errors found in the data, at which point the Data Manager printed a final hardcopy of the batch for Project Investigator validation/verification.

Project Investigator Validation/Verification

Project Investigator validation/verification, performed by the Project Investigators under the direction of the Data Manager, was similar in most respects to the method of keypunch verification. However, Project Investigator validation, unlike keypunch validation, involved comparing the printout with the original forms. This allowed any coding errors or inconsistencies to be detected. Any errors found were noted on the hardcopy printout, dated, and initialed by the Project Investigator who performs the validation/verification. Also, the SRF was updated, indicating whether or not errors were found. The batch, printout and SRF were then turned over to the Data Manager, who performed any and all corrections. Once all noted errors have been corrected, the SRF was again updated to indicate this, a new hardcopy printout was made, and the Data Manager gave the batch, printout and SRF back to the Project Investigator who performed a verification of corrections. This cycle was continued until there were no more validation errors found in the data, at which point the Data Manager printed a final hardcopy of the batch to be used in computer validation.

Computer Validation

This method involved the compilation of a variables' options and constant list for a batch compiled by the Project Investigator under the direction of the Data Manager. This list details all possible, "checkable", options and ranges which were valid for the batch variables. It does not list such things as actual lengths, weights, and other finite variables; however, the ranges provided indicated a problem (e.g., if a copepod is shown to have a length of 25 mm when the valid range is from 1 mm to 2 mm). The actual validation is performed via a validation algorithm, based on a general scheme of validation for any study (dates, cruises, stations, replicates, etc.) in addition to options designed for the batch and data set specifically. Due to its design, modification for specific options was easily performed interactively during program execution. The Data Manager created a file containing the variables' options and constants, and verified the information to match the original list. Then the computer validation program was run on the batch, at which time any batch specific options were indicated by the Data Manager to the program. The final output of the program was a file and hardcopy listing of any errors. This output included:

1. The location in the batch of the error;
2. The error;

3. Why the error was detected;
4. How the error was detected;
5. Whether the error was "constant" (perhaps the variables' options and constant list needs to be updated); and
6. The total number of errors found in the batch.

The Data Manager and the Project Investigator then used the information to trace the error(s). Once traced, the error was noted on the printout of the data, and the SRF was updated to indicate the batch progress at this point. The Data Manager performed any corrections, produced a new hardcopy printout, and re-ran the computer validation program. This cycle was continued until no further "computer-catchable" errors were found, at which time the SRF was updated to indicate that the batch was ready for incorporation into the data base. This method of data verification resulted in error rates of <0.5%.

A copy of the data files is then transferred to magnetic tape which has the following format: unlabeled, 9-track, 1600 bpi, 6160 fixed block format (blocking factor 77), 80 logical record size (blank-filled), EBCIDIC, tape density of 3. This tape is provided to NODC. Data are fully traceable through the system, with summary reports available at all times to indicate project status. Magnetic tapes containing the data files along with all relevant documentation and accompanying letters of transmittal will all have been provided at the time of draft final report submission.

After complete data verification the data set was ready for summarization and statistical treatment. Most data analysis was performed on Apple microcomputers using commercially available or custom designed software.

2.3.3.2 Statistical Analyses

All of the data analyses presented in this report are of a preliminary and exploratory nature, and the methods used do not necessarily represent those that will be used in the final report. Because of their preliminary nature, little justification is warranted, at present, concerning their appropriateness and use. This will be provided in the final report.

Clustering

The clustering presented in this report follows the method of NESS presented in Grassle and Smith (1976). This was performed with no taxa deleted following the description in the reference. The data used for these cluster analyses were the megafaunal counts and densities from trawl sampling. As noted in the description of the method, the parameter (m) specified for this analysis is the expected number of species shared. After several trial runs using various values of m, an m of 30 was selected to reflect similarities and dissimilarities in the dominant taxa.

Diversity and Evenness Calculations

All diversity calculations presented in this report were the Shannon-Weiner index of diversity computed as follows:

$$\dot{H}'' = -\Sigma_{j=1}^{S} \left(\frac{N_j}{N}\right) \log_e \left(\frac{N_j}{N}\right)$$

where

S = number of species,
N_j = number of individuals in the collection of species j,
N = $\Sigma_{j=1}^{S} N_j$ the total number of individuals in the entire collection.

The evenness calculation was made using the following:

$$V' = H''/\log_e(s)$$

These formulas and further descriptions of these summary statistics may be found in Pielou (1969).

The diversity and evenness values were calculated for species level data only. Ultimately we plan to make statistical comparisons of the diversity and evenness values. Following Bowman et al. (1971) the estimate of diversity has an approximately normal distribution. That is, the diversity from a single collection with sufficient number of individuals and species (see Bowman et al. 1971 for specific limits) is approximately normal with stable variance (i.e., with variance not depending on the underlying mean diversity).

Given normalcy and stable variance, Analysis of Variance on the calculated diversity and hence evenness values will be justified. The diversity will be calculated for each of the replicated macrofauna collections, and all replicates will be used in the ANOVAS.

As an ad-hoc test for single collection diversity (trawl collections of megafauna) the approximate sample standard errors are used in this report to construct 95% confidence intervals around the diversity estimates. The form of the standard error estimate is, following Hutcheson 1970:

$$\mathrm{Var}\ (H'') = [\Sigma_{j=1}^{s} \frac{N_j}{N} \log_e^2 (\frac{N_j}{N}) - (\Sigma_{j=1}^{s} \frac{N_j}{N} \log_e (\frac{N_j}{N}))^2]/N$$

Density Calculations

All densities appearing in the report derived from box core sampling are calculated as count divided by area and multiplied by the appropriate factor to give density in square meters or centimeters. The area sampled for each of the density calculations appears in the appropriate design table (see Appendices).

Density calculations for the trawl sampling was somewhat more complicated. The calculations involved first calculating bottom time of the net and multiplying this value times the ships speed to determine the distance the net was towed. This value was then multiplied times the width of the trawl to obtain the area sampled. The counts were divided by this area and multiplied by the appropriate factor to obtain number per hectare.

Length Weight Regressions

To determine the relationship between length or weight in the species accounts of megafauna, the usual log-log transformation was made. This was made after a significant deviation from linearity was observed in the raw length weight regression residual plots.

Bathymetric and Longitudinal Zonation Analysis

To evaluate whether bathymetric and longitudinal zones were suggested by the megafaunal species distributions, the analysis of species homogeneity found in Gage (1986) and Backus et al. (1965) was used. The approach used in the application of these procedures was to detect areas of species heterogeneity between stations. The application of the methods outlined in the above papers is straightforward. First, the empirical distribution of number of species starts and stops is generated. Next, the observed patterns of species starts and stops is compared to the homogeneous pattern using a Chi-squared test. Significant Chi-squared values for a start/stop point indicate a region of significant heterogeneity or discontinuity. For a more detailed description of this analysis see Backus et al. (1965).

In Section 4.3 the trawl collections of megafauna are described with the results summarized by depth interval. The project plan was for trawl collections to have been taken within defined bathymetric limits corresponding to Pequegnat's (1983) faunal assembages as defined previously (see Section 1.2). With the trawl collections, maintaining the sampling within the defined bathymetric limits proved difficult because (1) the hauls were long, (2) the bathymetry maps used to plan the tows were not necessarily accurate nor precise on the spatial scale being sampled, and (3) other considerations (e.g., safety) sometimes dictated the ships course while underway.

When the depth ranges covered by each trawl-tow over all cruise/station combinations were plotted it was found that, overall, the samples were best summarized by six depth intervals:

Median Depth Within Interval Sampled (m)	Overall Depth Interval Sampled (m)
375	328- 423
608	465- 750
876	751-1000
1275	1050-1500
1800	1550-2050
2478	2100-2855

The differences between median depths, from shallow to deep, were 233, 268, 399, 525 and 678 m. The depth difference between sampled depths increased over the depth range and this factor may account for some of the observed differences; i.e., some apparent faunal breaks may be more related to a greater depth-wise "distance" between some stations as opposed to others, than to real faunal breaks.

3.0 PHYSICAL AND CHEMICAL RESULTS

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3.0 PHYSICAL AND CHEMICAL RESULTS

3.1 HYDROGRAPHY

Tabulated results of hydrographic profiles taken at five stations on each cruise are shown in Appendix B1 of Volume III of this report series. Depth related changes in physical and chemical constituents followed expected trends, with some variation by cruise and station location within the Gulf. Surface to bottom profiles of temperature, salinity, dissolved oxygen, phosphate, nitrate, and silicate values for each cruise are provided in Attachment A1.1.

3.1.1 TEMPERATURE

From the surface (upper 25 m) to approximately 1300-1400 m depths temperature dropped from near 20° (19.01-25.08°C) to about 4.22-4.35°C at 1300-1400 m depth (Fig. 3-1). Below 1400 m temperatures remained constant within this low range. Between 300 and 1400 m, temperature variations by depth within transects was not great. On the central transect, Stations C1, C2, C3, C4 and C5 were each occupied three times (Cruise I-III). The maximum variations over the three cruises at representative depths of 300, 600, 900, and 1400 m were 2.59°, 0.78°, 0.29°, and 0.10°, respectively.

Similarly on Cruise IV in the eastern Gulf, profiles were measured at stations with bottom depths of 380, 665, 885, 915, and 2920 m. Temperature variations by depth along the transect were low; ranges were 1.93° (18.35-20.28°C) at 100 m; 1.72° (9.31-11.03°C) at 400 m; 0.68° (7.05-7.73°C) at 600 m and 0.16° (5.10-5.26°C) at 900 m.

On a large scale, temperature differences from the western to the eastern Gulf also showed only minor changes (Fig. 3-2). From the western to the eastern Gulf the most temperature variation by depth was only 0.49°C at 275-m depth.

3.1.2 SALINITY

Salinity profiles exhibited the characteristic pattern for the Gulf of Mexico (see Attachment A1.1). Surface salinity ranged from about 35 to

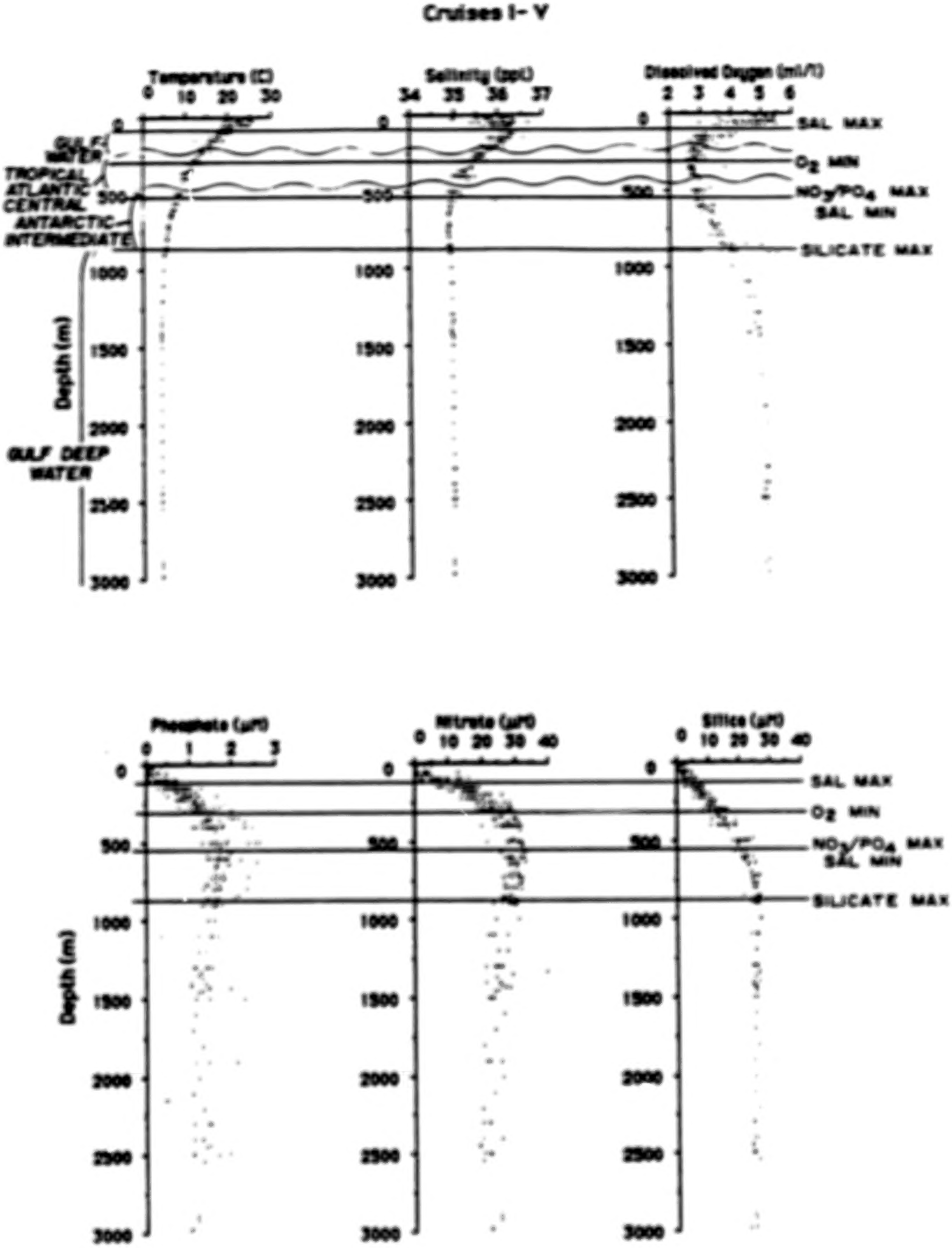

Figure 3-1. Hydrographic profiles, all cruises combined.

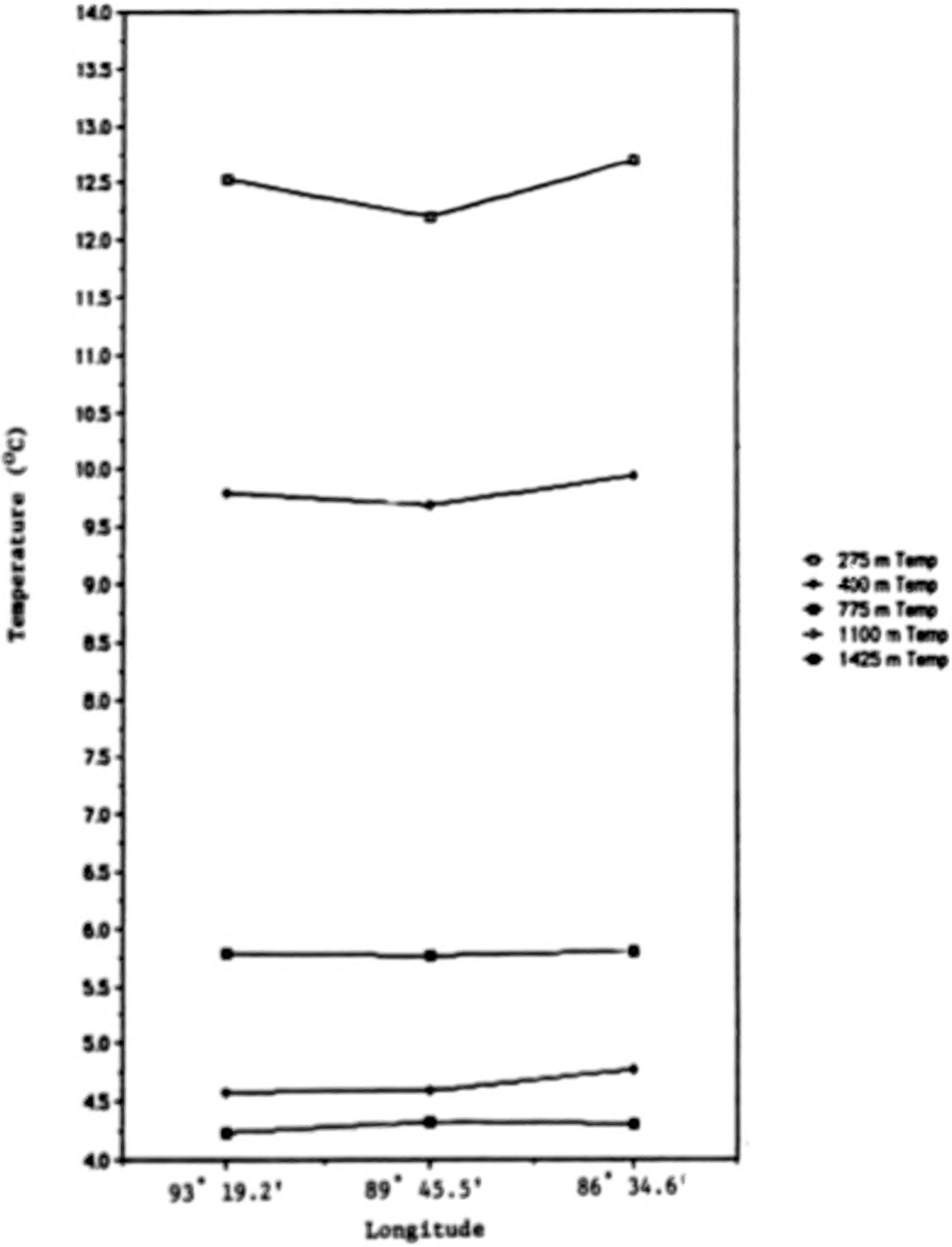

Figure 3-2. Variation in temperature at selected depths measured at 3 stations (W4, C4, E4) across the Gulf during Cruise II.

about 36.5 °/oo and increased with depth to about 100-200 m where the salinity maxima, characteristic of the core of the Gulf Common Water, is found (Fig. 3-1). Below the salinity maxima, salinity decreased to a depth of about 600-800 m where the salinity minimum is located. The salinity minimum is used as an indicator of the core of the Antarctic Intermediate Water Mass.

Using the same depths that were used above to compare seasonal temperature differences by depth along the central transect stations during Cruises I-III, salinity showed the following variability for depths between 300 and 1400 m:

Depth	Extreme	Range
300 m	35.16-35.70 °/oo	0.54 °/oo
600 m	34.90-34.94	0.04
900 m	34.89-34.95	0.06
1400 m	34.94-34.98	0.04

Thus, less than 0.1 °/oo salinity variation was observed for any depth on the Central Transect over three cruises.

Longitudinal variations in salinity based on measurements taken during Cruise II at similar depths from stations in the western, central and eastern Gulf are shown in Figure 3-3. At 275 and 400 m salinity was slightly higher in the eastern Gulf, with the central Gulf station (C4) having the lowest salinity at these depths. (Extreme difference of 0.07 °/oo.) At 775 m and below (1100-1400 m) there was a slight but general decrease in salinity from west to east (less than 0.04 °/oo difference). These differences were less than the observed difference along the central transect at similar depths over three cruises for December 1983 to November 1984.

3.1.3 DISSOLVED OXYGEN

Dissolved oxygen concentration (Fig. 3-1) ranged from about 2.5 to 5.5 ml/l (= ~3.6-7.8 mg/l). These concentrations are not considered to be limiting to aerobic fauna found in the ocean. Dissolved oxygen concentrations were higher in the surface waters (<50 m) decreasing to the

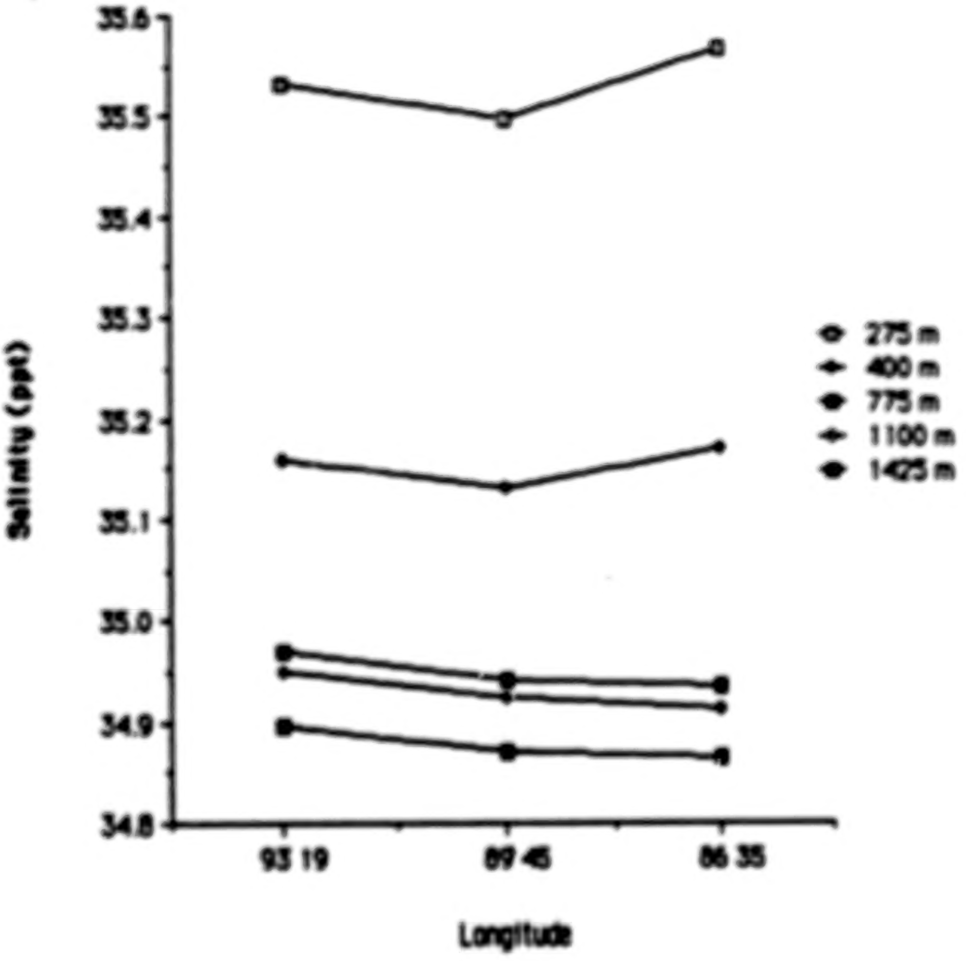

Figure 3-3. Variation in salinity at selected depths measured at 3 stations (W4, C4, E4) across the Gulf during Cruise II.

oxygen minimum layer (about 400 m depth), which is used to identify the Tropical Atlantic Central Water Mass. In the eastern Gulf, a secondary oxygen minimum layer at 150 to 300 m is sometimes found, associated with the Eastern Gulf Loop Current (Nowlin and McLellan 1967). This phenomenon was apparently present during Cruise II, on the eastern transect station E4, where two oxygen minima were observed (one at 174 and one at 400 m.

Below the oxygen minimum, D.O. concentrations increased to a depth of approximately 1500 m. From 1500 m to 2200 m dissolved oxygen concentrations remain relatively constant at approximately 5 ml/l. Station WC12 sampled on Cruise V produced some anomalous D.O. results although temperature and salinity profiles were normal (see circled values on Fig. 3-1; see Fig. A1.1-7 in Attachment A1.1). No explanation other than sample handling or analytical error have been postulated for these results, although there is no reason to expect these.

Across the Gulf, dissolved oxygen levels varied less than 0.2 ml/l at a given depth except for measurements made at 1400 m (Fig. 3-4). The 1400 m depth is an area of increasing D.O. levels and small-scale differences in depth of measurement would have more impact than measurements made at other depths.

3.1.4 NUTRIENTS

Nitrate, phosphate and silicate concentrations are used as indicators of Antarctic Intermediate and Gulf Deep Water Masses. The nitrate and phosphate maxima, which usually coincide along with the salinity minimum, delineate the core of Antarctic Intermediate Water while the silicate maximum marks the upper boundary of Gulf Deep Water (a mixture of North Atlantic Deep Water and Carribbean Midwater Masses).

Nitrate levels increased from near zero at the surface to ~30-33 µM at 500-700 m depths (Fig. 3-1). Below 500-700 m there was a gradual decrease to about 20 µM (Fig. 3-1). Phosphate levels followed a similar pattern with maximum values of 2.0-2.6 µM (Fig. 3-1). Both nitrate and phosphate levels usually exhibit marked increases at about 100-200 m, probably a result of decreased photosynthetic activity.

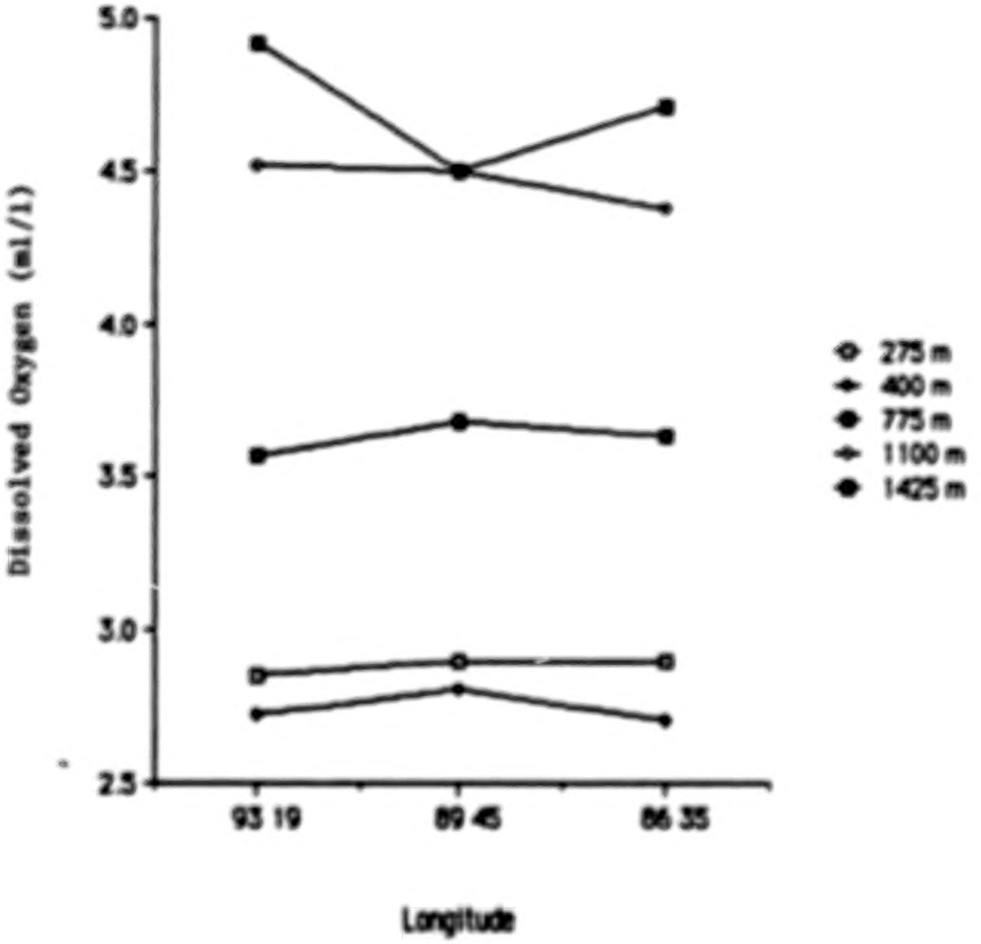

Figure 3-4. Variation in dissolved oxygen at selected depths measured at 3 stations (W4, C4, E4) across the Gulf during Cruise II.

On Cruise II, there was a general west to east increase in nitrate concentrations below 275 m with maximum values observed on the Central Transect (Fig. 3-5). Phosphate concentrations by depth were usually lower in the east with maximum values in the west or central transect depending on depth (Fig. 3-6).

Silicate concentrations showed less variability at a given depth than either phosphate or nitrate (Fig. 3-1). Silicate levels increased from near zero values at the surface to maximum values of about 25 to 30 µM at ~800-1000 m. From these depths to the bottom, values decreased on the order of 1-5 µM down to ~ 3000 m. Values were less variable with increased depth.

3.1.5 PARTICULATE ORGANIC CARBON (POC)

POC values ranged from 1 to 83 µgC/l (Appendix Table B1). Many of the higher values were observed at depths of less than 100 m with a tendency for lower levels to be associated with increased depth. However, levels in the 30-45 µgC/l range were observed across 500-2500 m depths. A general decrease from west to east was observed in POC values during Cruise II (Fig. 3-7).

3.1.6 DISSOLVED ORGANIC CARBON (DOC)

Dissolved organic carbon concentrations, measured on Cruises II, III, and V, decreased with depth. In the top 100 m, values usually were greater than 1.0 mgC/l--at times reaching 2.85 mgC/l. Below 100 m, levels were usually from 0.5 to 0.9 mgC/l although the maximum value observed was 2.85 at 299 m (Cruise III, Station C3).

3.2 SEDIMENTS

3.2.1 SEDIMENT CLASSIFICATION

Sediments were classified into categories using the graphical sediment triangle representing percentages of sand, silt and clay in the sample. Forty-five stations were sampled during a total of five cruises.

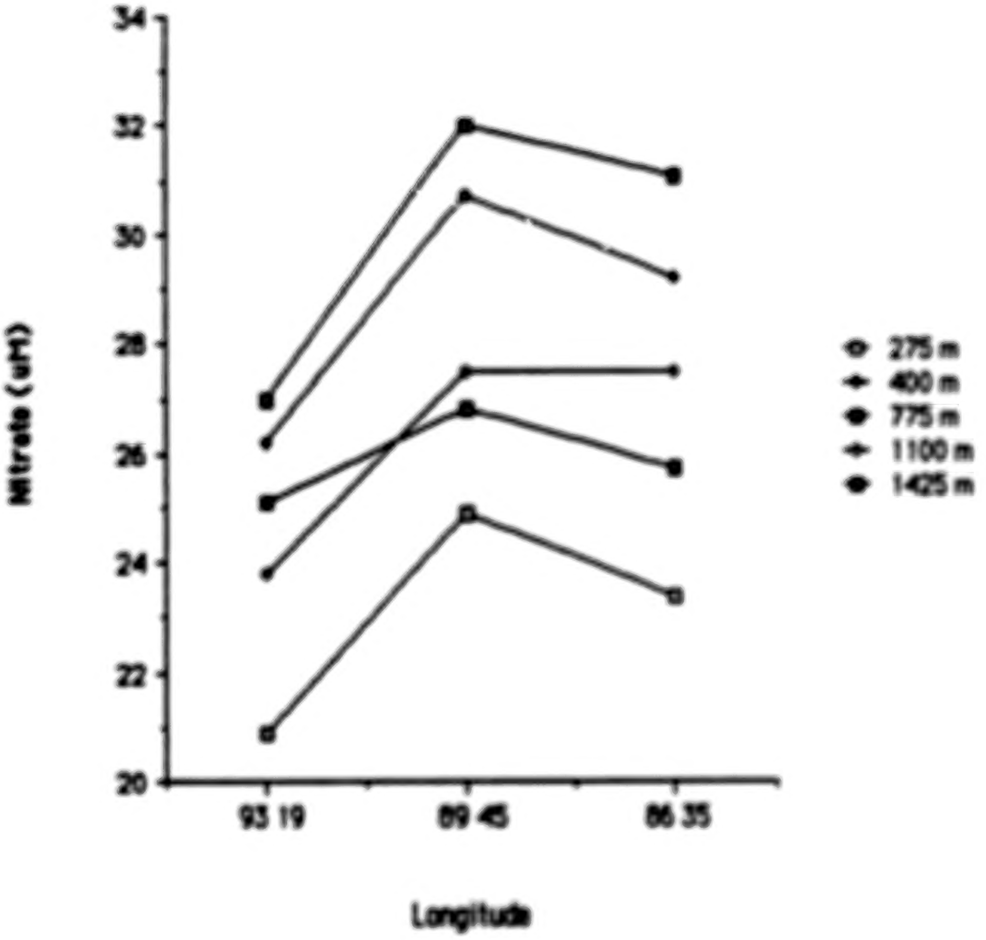

Figure 3-5. Variation in nitrate at selected depths measured at 3 stations (W4, C4, E4) across the Gulf during Cruise II.

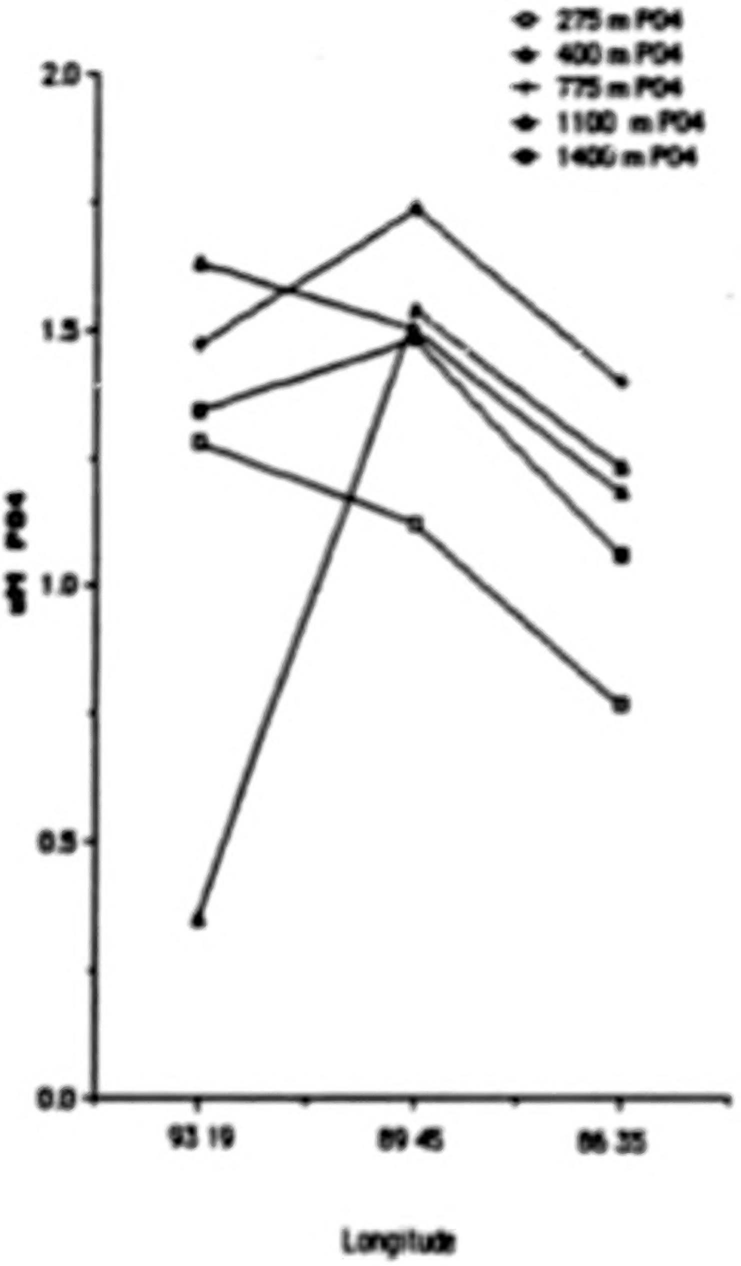

Figure 3-6. Variation in phosphate at selected depths measured at 3 stations (W4, C4, E4) across the Gulf during Cruise II.

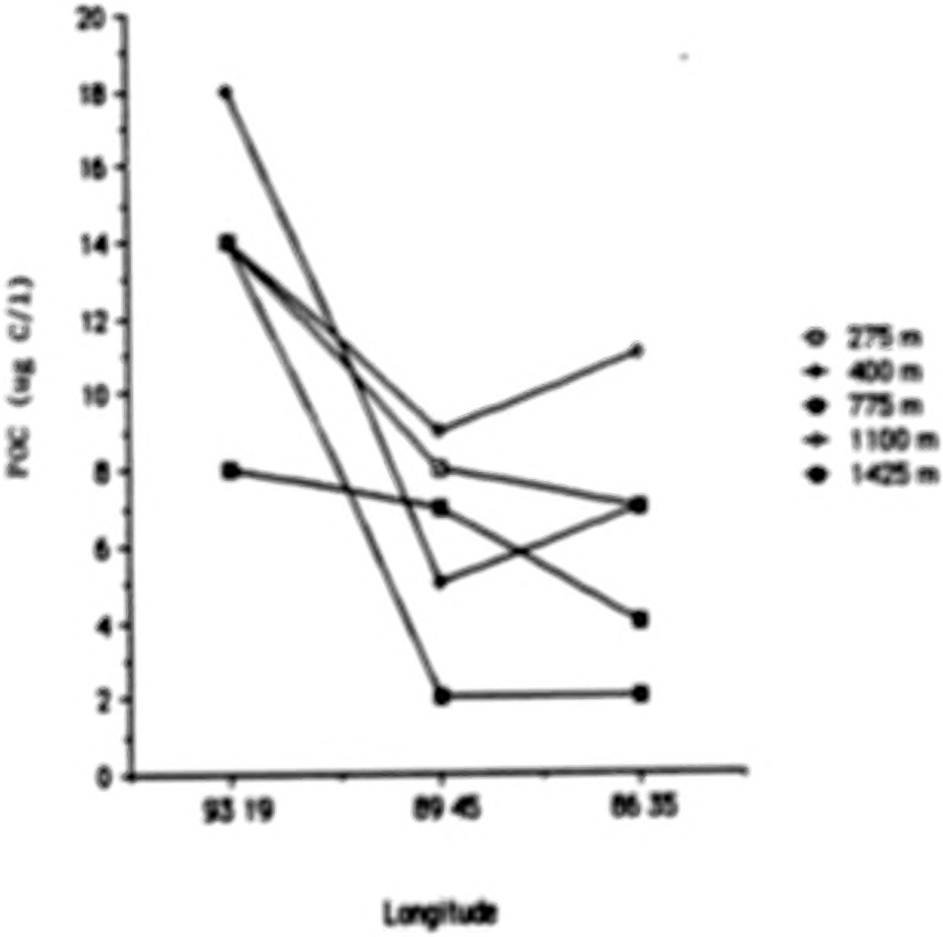

Figure 3-7. Variation in particulate organic carbon at selected depths measured at 3 stations (W4, C4, E4) across the Gulf during Cruise II.

Five of these stations (C1-C5) were occupied three times and four (E1-E3, E5) were occupied twice. This resulted in a total of 59 station measurements with replicated sediment measurements for which the data are summarized in Attachment A1.2.

As summarized in Figure 3-8, the most common (over 55% of the stations) sediment type was silty-clay found in all areas of the Gulf. (For detail, see Figs. A1.2-1 through A1.2-5 in Attachment A1) There were small amounts of variation within this type depending on the areas of the Gulf sampled. In the eastern Gulf this type had slightly higher percentages of sand than in the western or central areas (Attachment A1, Figs. A1.2-6 through A1.2-12). Along the Central Transect there were slightly higher percentages of silt than clay at the deeper stations C5 and C12.

The second most common sediment type was clay, represented by nine stations in the western and central Gulf at relatively shallow stations (<1226 m). Stations with clay sediments were relatively uniform--i.e., with little variation in the sand-silt-clay proportions.

Sandy clay was observed in the western Gulf at Stations W1, W2, W5 on Cruise II; at WC5 on Cruise V; and in the eastern Gulf at Station E5 on Cruise II. At Station E5 on Cruise IV, the sediment was predominantly clay with approximately equal mixtures of sand and silt, compared to the Western Transect station which had sand in higher proportions than silt (see Attachment A1, Figs. A1.2-6 through A1.2-12).

The sediment type "sand-silt-clay" has approximately equal proportions of each sediment size fraction. Sand-silt-clay sediment was found in the eastern Gulf at Stations E1, E1b, E1c and E2d (at these shallow stations clay was the most abundant of the three parameters and sand was the smallest fraction) and at E4 where clay was the largest fraction but the sand proportion was higher than silt.

Station WC-6 (Cruise V) was difficult to characterize because of the variation among the six replicates. Silty clay is probably the best classification based on average values.

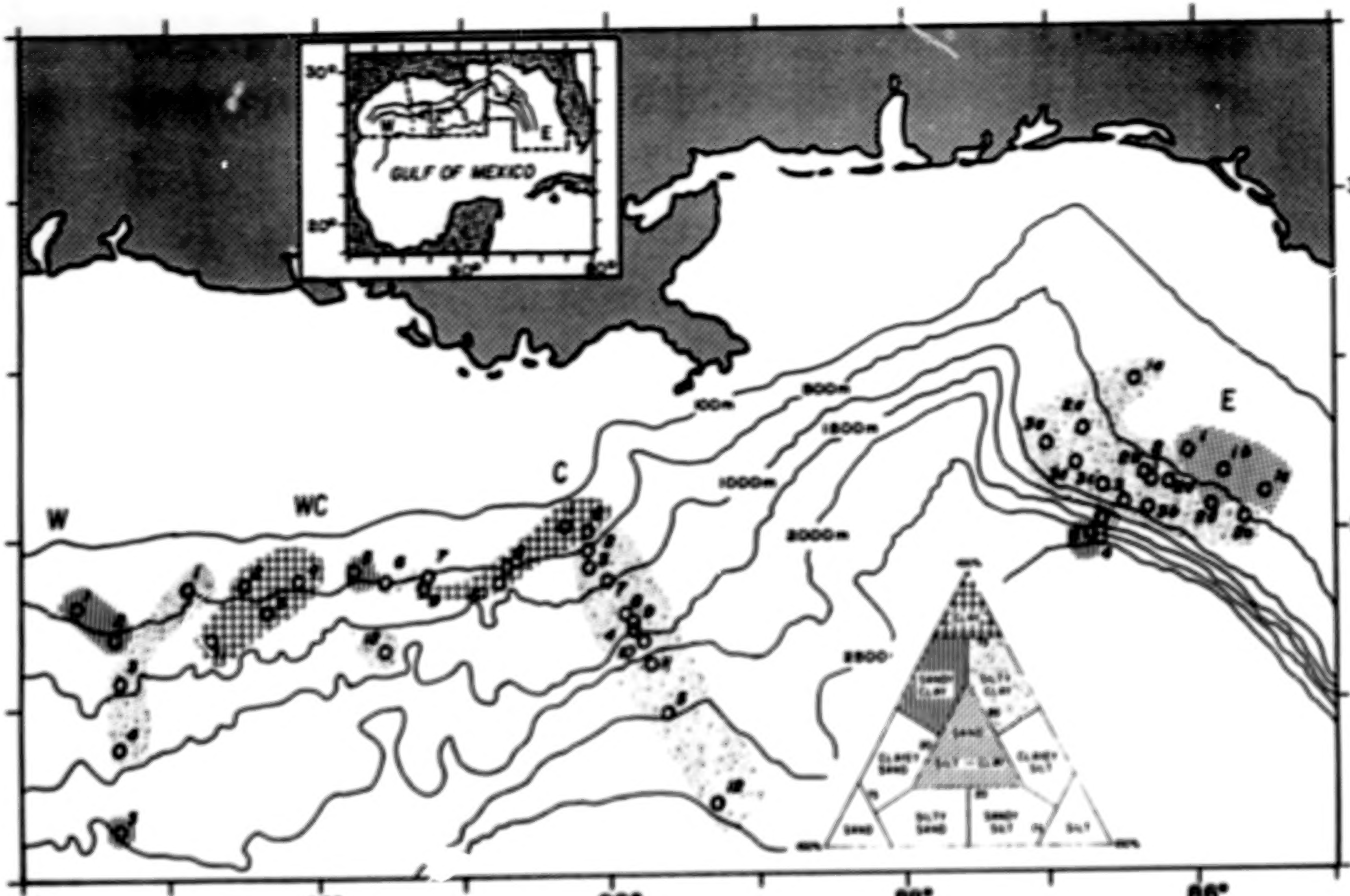

Figure 3-8. Sediment map.

3.2.2 SEDIMENT HYDROCARBONS

Sediments on the Gulf of Mexico continental slope contain a mixture of terrestrial, petrogenic and planktonic-sourced hydrocarbons. The molecular-level alkane distribution was similar in all samples, but the quantitative importance of the three major sources varied with location, time of sampling, and depth. Hydrocarbon concentrations were relatively uniform across the slope, given the large geographical area studied.

Concentrations (µg/gm dry weight of sediment) ranged from 4.0 to 94.2 for extractable organic matter, from 0.1 to 5.2 for the aliphatic hydrocarbons, and from 0.7 to 81.4 for the aliphatic unresolved-complex-mixture (Table 3-1). A comparison with previous studies presented in Table 3-2 shows that these concentrations are generally lower than reported values for Gulf of Mexico sediments. However, the baseline values in Table 3-2 are primarily for coastal and shelf sediments.

Individual hydrocarbon compounds were detected at concentrations of <0.01 to >0.5 µg/g. In general, the qualitative molecular-level alkane distribution was similar at all sites sampled. The dominant normal alkane between n-C_{15} and n-C_{22} was variable, whereas between n-C_{23} and n-C_{32} the dominant n-alkanes were consistently n-C_{29} or n-C_{31}. The alkane distribution in samples from the Central Transect during Cruise I are typical of all locations sampled (Fig. 3-9). Detailed sediment hydrocarbon data for each station are found in Appendices B-4, B-5, and B-6.

3.2.2.1 Hydrocarbon Sources--The Approach

Molecular-level and bulk parameters can be used to estimate the relative importance of hydrocarbon sources at a given location. These parameters are based on the premise that a hydrocarbon source has a unique "fingerprint", i.e., a recognizable suite of compounds. In nature, however, few unique end-members occur. Several diagnostic indicators were monitored to better understand the dynamics of hydrocabons in Gulf of Mexico slope sediments (see Table 3-3).

Table 3-1. The ranges and averages for selected hydrocarbon parameters in Gulf of Mexico continental slope sediments (ug/g dry weight of sediment).

Cruise	Location (Transect)	Extractable Organic Matter (ppm)	Aliphatic Hydrocarbons (ppm)	Aliphatic Unresolved-Complex-Mixture (ppm)
I	Central	28.4 (13.9 - 61.3)[1]	1.6 (1.3 - 2.0)	23.3 (19.3 - 29.8)
II	Central	21.7 (18.0 - 25.2)	1.7 (1.6 - 1.8)	8.9 (6.0 - 14.0)
	Western	26.0 (14.0 - 55.2)	1.1 (0.8 - 1.3)	11.1 (5.2 - 11.4)
	Eastern	8.6 (7.6 - 10.9)	0.7 (0.5 - 1.0)	5.4 (3.2 - 7.3)
III	Central	18.1 (4.0 - 44.4)	1.4 (0.6 - 4.6)	9.7 (4.4 - 17.4)
IV	West/Central	30.0 (17.7 - 94.2)	0.9 (0.4 - 5.2)	16.8 (4.2 - 81.4)
V	Eastern	7.2 (4.7 - 13.4)	0.2 (0.1 - 0.4)	2.0 (0.7 - 5.0)

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[1] Ranges in values.

Table 3-2. Summary of Gulf of Mexico sediment hydrocarbon analyses.

Location	Concentrations in µg g^{-1} Total HC	 Saturated HC	Predominant Source	Reference
Texas/Louisiana - Coastal	20-190		B(P)	Smith, Jr. 1952
Texas/Louisiana - Coastal	Low Concentrations[1]		B	Stevens et al. 1956
Gulf of Mexico - Coastal	Biogenic Waxes[2]		B	Bray and Evans 1961
Florida (Bay) - Sandy Sediments	Avg.=4.4[2]	Avg.=2.0[2]	B	Palacas et al. 1972
- Muddy Sediments	Avg.=86.0[2]	Avg.=30.0[2]	B	
S.E. Coast - Sandy Sediments	0.2-10.0[2] Avg.=4.25	0.1-3.8[2] Avg.=1.4	B(P)	Palacas et al. 1976
STOCS* - Coastal	Very low levels[2]		B(P)	Palacas et al. 1976
STOCS - Coastal (Before, during and after drilling activities)	0.22-5.60[2] Avg.=1.14	(0.1-0.5)[2] Avg.=0.2	B(P)	Parker et al. 1976
Texas/Louisiana - Coastal Banks	0.03-0.80[2]		B	Parker 1978
MAFLA**- Nearshore Florida (<40 m)	Avg.=1.90[2]	0.29-1.60[2] Avg.=0.86	B	Boehm 1979
- >40 m Florida	Avg.=1.39[2]	0.29-1.89[2] Avg.=0.83	B(P)	
- Mississippi/Alabama Shelf	Avg.=1.61[2]	0.28-2.89[2] Avg.=1.1	B(P)	
Freeport, Texas - Coastal	0.9-89[2] Avg.=39.7	0.1-2.4[2] Avg.=0.71	B	Slowey 1980
Texas/Louisiana - Coastal	5.71-87.2[2] Avg.=39.7	3.13-49.5[2] Avg.=21.4	B(P)	Shilton et al. 1981
Texas Shelf	Avg.=1.3[2]		B	Lytle and Lytle 1979
Florida Coastal (<50 m)	Avg.=3.1[2]		B	Gearing et al. 1976
W of Mississippi R. Coastal (<50 m)	Avg.=11.7[2]		B(P)	Gearing et al. 1976

[1] Method - gravimetry (expressed as a percentage of the total organic extract recovered from the silica gel).
[2] Method - GC, GC/MS.
* South Texas Outer Continental Shelf
**Mississippi Alabama Florida
[B] Biogenic.
[P] Petrogenic.

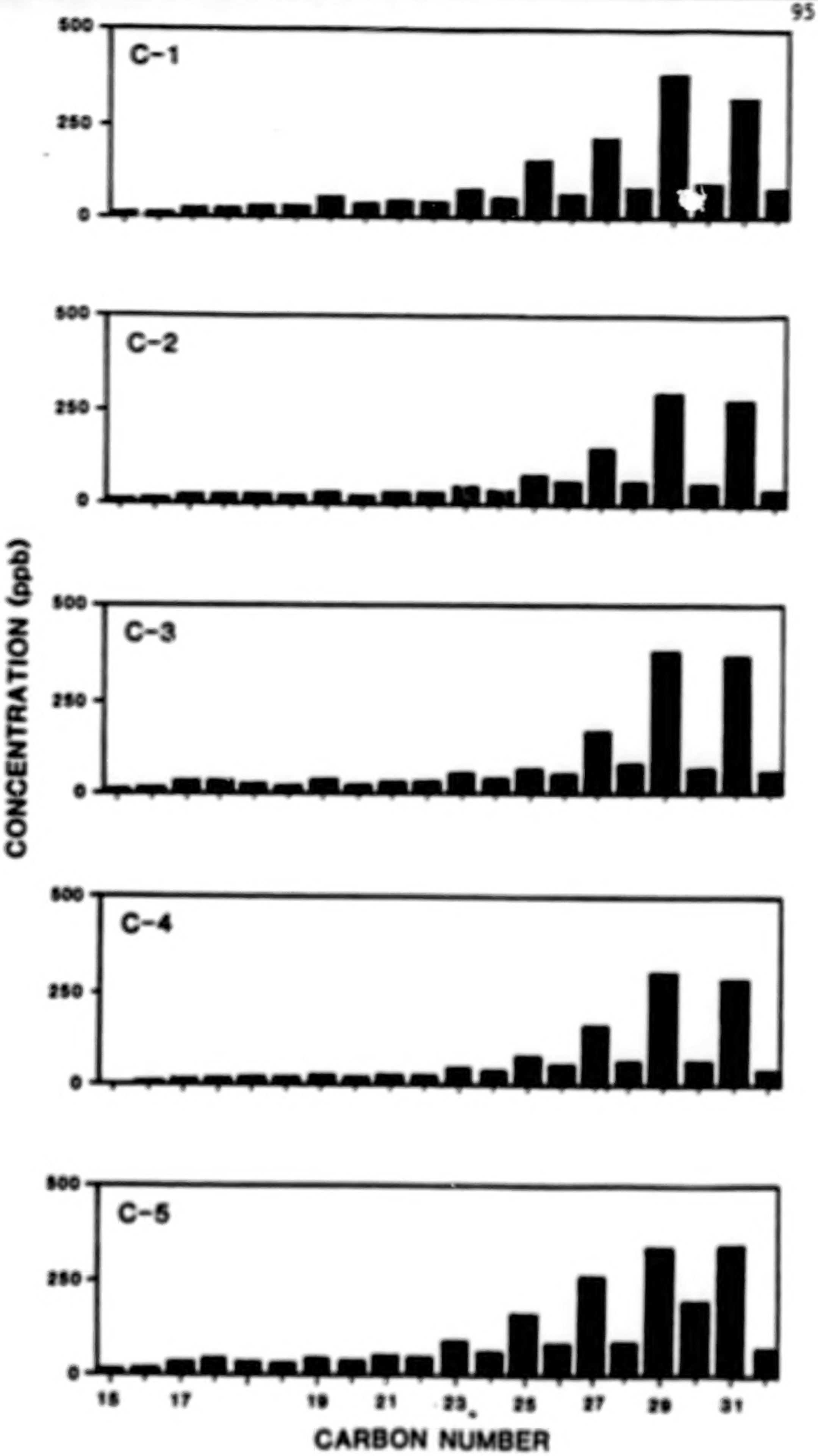


Figure 3-9. Molecular level alkane distributions for sediments from the central transect during Cruise I (ng/g dry wet of sediment,ppb).

Table 3-3. Suggested molecular-level indicators of specific hydrocarbon sources to sediments on the Gulf of Mexico continental slope.

Indicator Compound	Source	Abbreviation
n-$C_{15, 17, 19}$ and Pristane	Planktonic/Petroleum	PL-1
n-$C_{16, 18, 20}$ and Phytane	Petroleum/(Planktonic?)	PE-Lo
n-$C_{25, 27, 29, 31}$	Land/(Petroleum)	TERR
n-$C_{24, 26, 28, 30}$	Petroleum/(Biogenic)	PE-Hi
Unresolved-Complex-Mixture	Petroleum/(Biogenic?)	UCM

Certain assumptions need to be understood in order to properly evaluate these distributions as indicators of hydrocarbon sources. Plankton generally produce a simple mixture of hydrocarbons, including n-C_{15}, n-C_{17}, n-C_{19} and pristane, so the presence of these compounds can indicate a planktonic hydrocarbon source (PL-1). Petroleum also contains these compounds, but usually also contains comparable amounts of the alkanes n-C_{16}, n-C_{18}, n-C_{20}, and phytane as well. Thus a low molecular weight petroleum indicator (PE-Lo) can be used to assess the petroleum component of the planktonic indicator. To make this calculation we assume that the contribution of petroleum to each indicator is equal; therefore the planktonic component can be inferred as the diffference between PL-1 and PE-Lo. Straight chain biowaxes with n-C_{25}, n-C_{27}, n-C_{29}, and n-C_{31} alkanes have been used extensively as an indicator of terrestrial or land-derived input. As such, the sum of these four normal alkanes can be used to indicate the terrestrial (TERR) hydrocarbon component. As with the planktonic indicator, these normal alkanes can also have a source in petroleum. Again, in general, petroleum also contains a near equal amount of the even alkanes n-C_{24}, n-C_{26}, n-C_{28}, and n-C_{30} (PE-Hi). As in the planktonic indicator, the terrestrial component can be estimated by subtracting the PE-Hi from the TERR concentration. Plants themselves can also contain significant amounts of indigenous even carbon alkanes; thus this type of indicator provides a measure of maximum petroleum contribution and a minimum terrestrial contribution over this molecular weight range. In summary the planktonic input is estimated as [(PL-1)-

(PE-Lo)], the terrestrial input as [TERR)-(PE-Hi)], and the petroleum input as [(PE-Lo)+(PE-Hi)]. These parameters are used to assess hydrocarbon inputs and not bulk organic matter since hydrocarbons represent only a small fraction of the total organic carbon present in a sediment.

These parameters, with the above mentioned limitations, can be used to study the hydrocarbon dynamics on the continental slope as a function of water depth, location, and time of sampling. Also included is the evaluation of parameters such as the unresolved-complex-mixture (UCM), an indicator of petroleum input; the carbon preference index (CPI), an indicator of the relative amounts of odd and even normal alkanes; and bulk sediment characteristics.

3.2.2.2 Areal Distribution

Cruise II assessed the distribution of sediment hydrocarbons on transects from the central, western, and eastern Gulf of Mexico continental slope. Extractable organic matter (EOM) is a composite of biogenic and petroleum related material. Extractable organic matter concentrations were generally lowest on the Eastern Transect and nearly equal on the Western and Central Transects, with the exception of Station W1 (Fig. 3-10). The aliphatic unresolved-complex-mixture (UCM), a petroleum indicator, was similar over all three transects though slightly elevated in Western Transect sediments (see Table 3-1). The elevated EOM at Station W1 was due to an increased UCM i.e., petroleum component.

The amount of terrestrial hydrocarbons decreased from the Central to the Western to the Eastern Transect (Figs. 3-11 and 3-12). Terrestrial hydrocarbon concentrations, as indicated by the sum of n-C_{25}, n-C_{27}, n-C_{29}, and n-C_{31} (TERR) concentrations, were relatively uniform with water depth on the Central and Western Transects; whereas terrestrial hydrocarbons increased with water depth on the Eastern Transect. The influence of the land- and/or river-derived material was readily apparent in all three regions and accounts for a majority of the GC-resolvable alkanes.

In general, planktonic inputs accounted for less than 10% of the GC-resolvable alkanes. Sediment biogenic hydrocarbons on the slope were

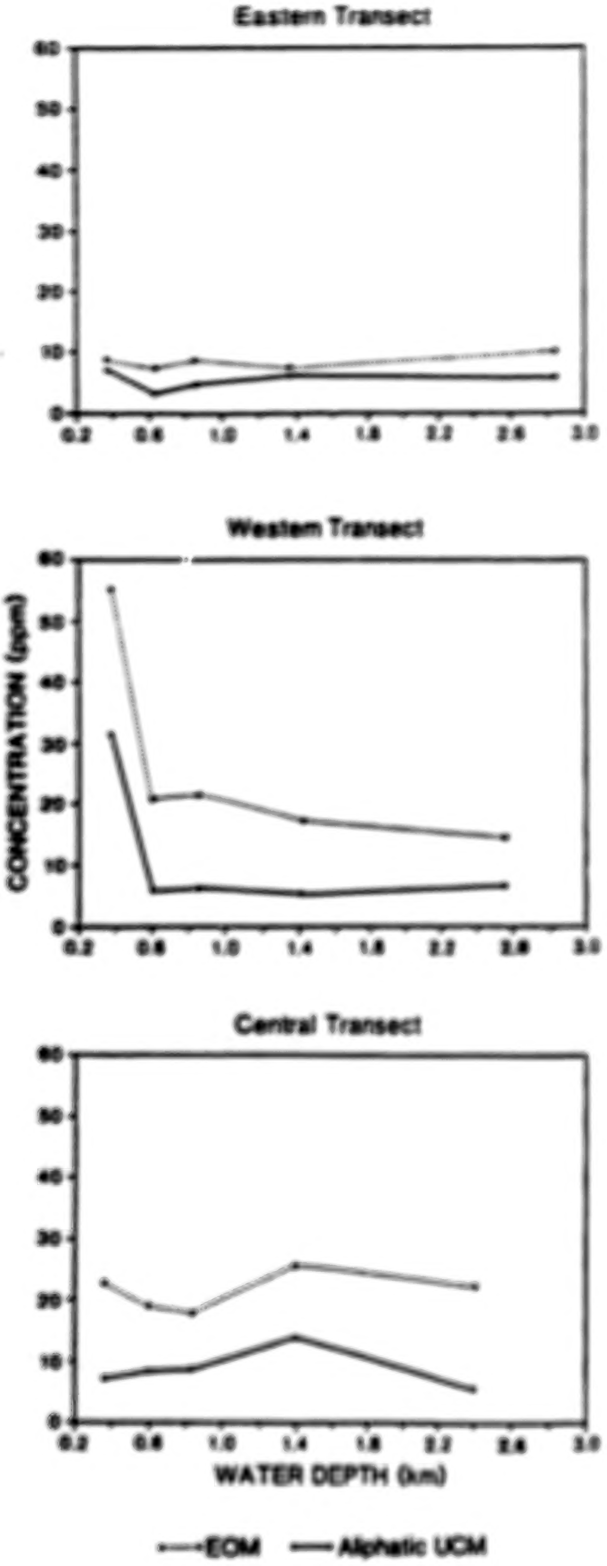


Figure 3-10. Variation in extractable organic matter (EOM) and the aliphatic unresolved complex mixture (UCM) along transects on the eastern, western, and central Gulf of Mexico continental slope.

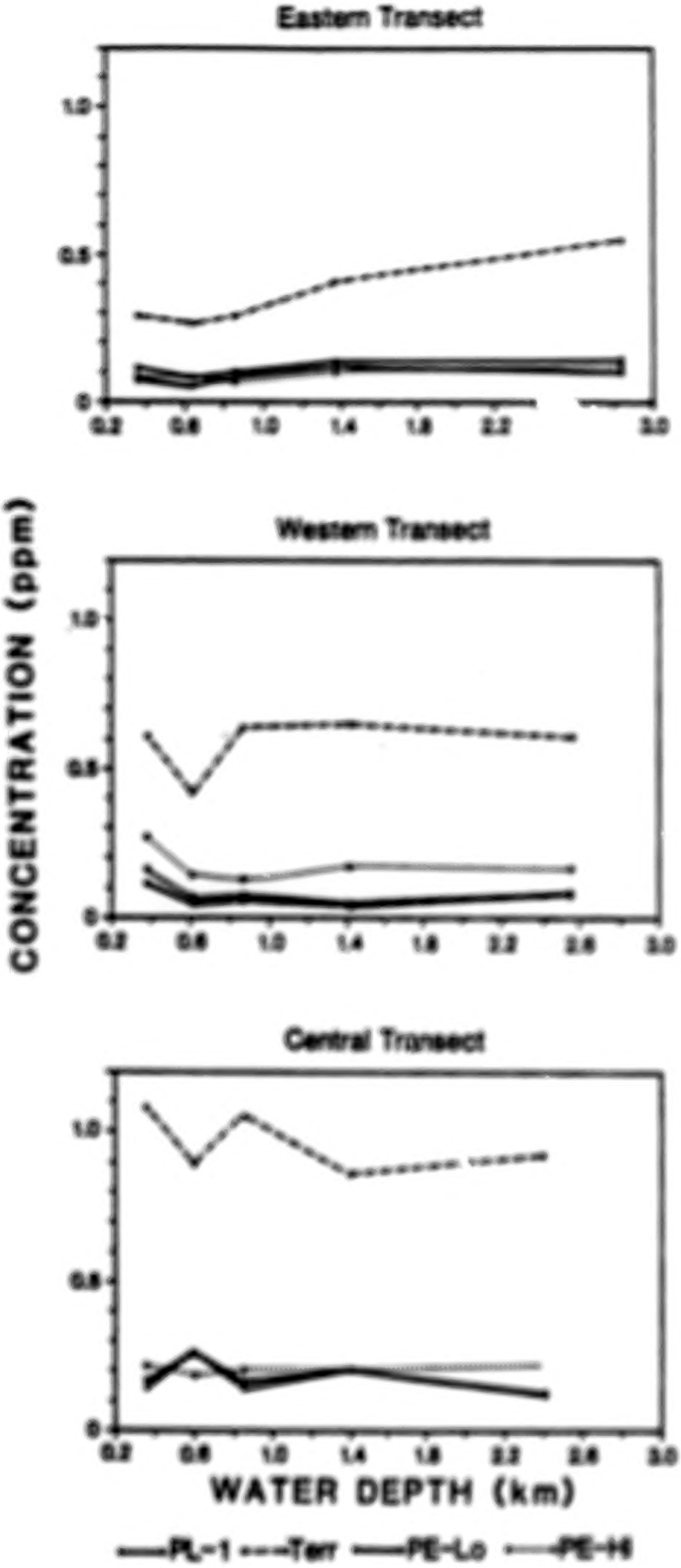
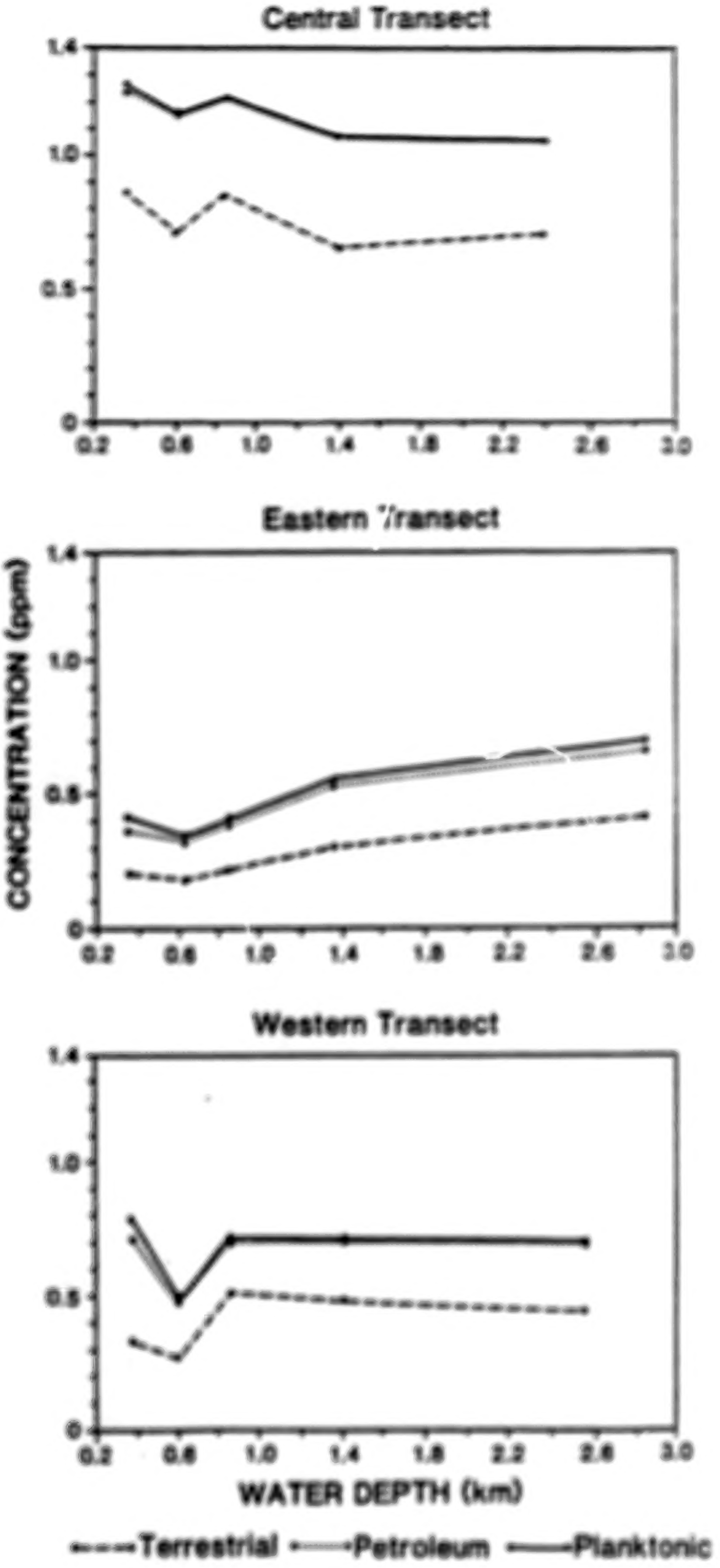


Figure 3-11. Variation in hydrocarbon source parameters along transects in the eastern, western, and central Gulf of Mexico continental slope (for definition of source parameters see Table 3-3).



Central Transect

Eastern Transect

Western Transect

Figure 3-12. Variation in planktonic, terrestrial, and petroleum hydrocarbons along three transects presented as a cumulative concentration (i.e., the first concentration plotted is terrestrially sourced hydrocarbons, second is terrestrial + petroleum, and third is terrestrial + petroleum + planktonic).

dominated by the more resistant terrestrial components and the degree of dominance was a function of proximity to the Mississippi River and delta. The steepness of the slope and the prevailing currents affect the observed distributions as well. Planktonic inputs were low and often difficult to discern on the Central and Western Transects (Figs. 3-11 and 3-12). The planktonic input was generally higher at the shallower stations of these two transects. The low planktonic hydrocarbon concentrations on the Central and Western Transects may be due to a high sedimentation rate and/or dilution with riverine material. On the Eastern Transect the planktonic input was discernible and relatively constant with depth.

Petroleum inputs, measured both by alkane parameters and the unresolved-complex-mixture, were detected at all sites (Figs. 3-11 and 3-12). In general, petroleum input was greatest on the Central Transect, with lesser amounts at the Western and Eastern Transects. The maximum estimate of petroleum-sourced hydrocarbons indicates relatively low concentrations at all locations. To determine if the petroleum hydrocarbons detected were due to transported terrestrial particles (most likely by mass movement and turbidity flows after initial deposition near the river's mouth) or to upward migration from deeper reservoired petroleum, the petroleum indicators were compared with the terrestrial and planktonic indicators (Fig. 3-13). These comparisons suggest a dual source for the sediment petroleum hydrocarbons. Low molecular weight hydrocarbons (PE-Lo) correlate with a terrestrial input on the Eastern Transect, but not on the Central and Western Transects. The higher molecular weight petroleum indicator (PE-Hi) also correlates with the terrestrial indicator (TERR) on the East but not on the other transects.

An estimate of the amount of petroleum hydrocarbons is provided by the UCM. The UCM was generally independent of the planktonic or terrestrial input (Fig. 3-14) which suggests an additional source of hydrocarbons (such as upward migration from deeper reservoirs) on the Central and Western Transects. An anomaly was seen at Station W1, which contains petroleum hydrocarbon concentrations that were significantly elevated in comparison with other Western Transect stations.

This attempt to correlate petroleum and terrestrial sediment inputs assumes that the ratio of petroleum to terrestrial hydrocarbons transported to a location is constant with time, which may or may not be

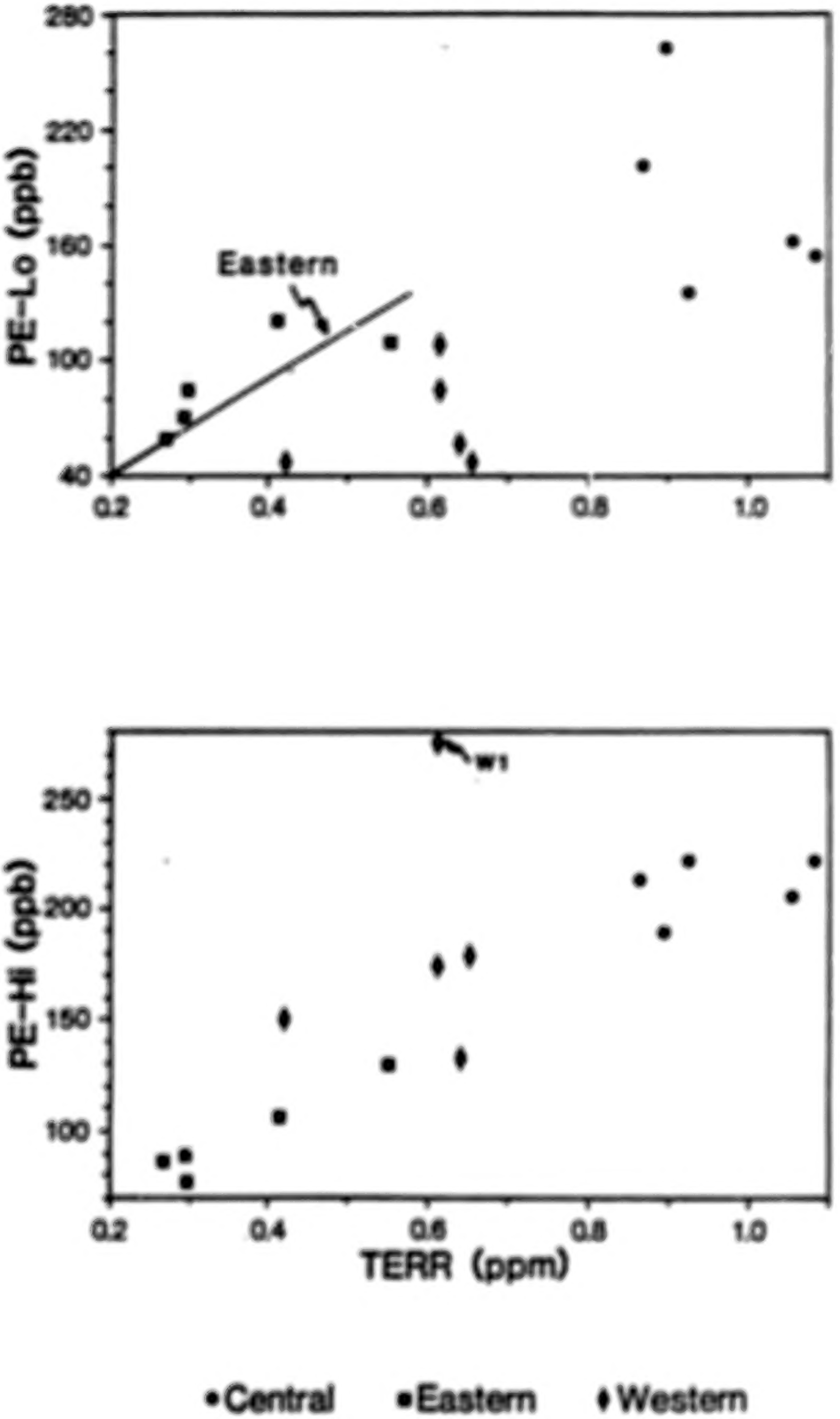


Figure 3-13. The relationship between alkane petroleum indicators and a terrestrial indicator (for definition of the indicators see Table 3-3).

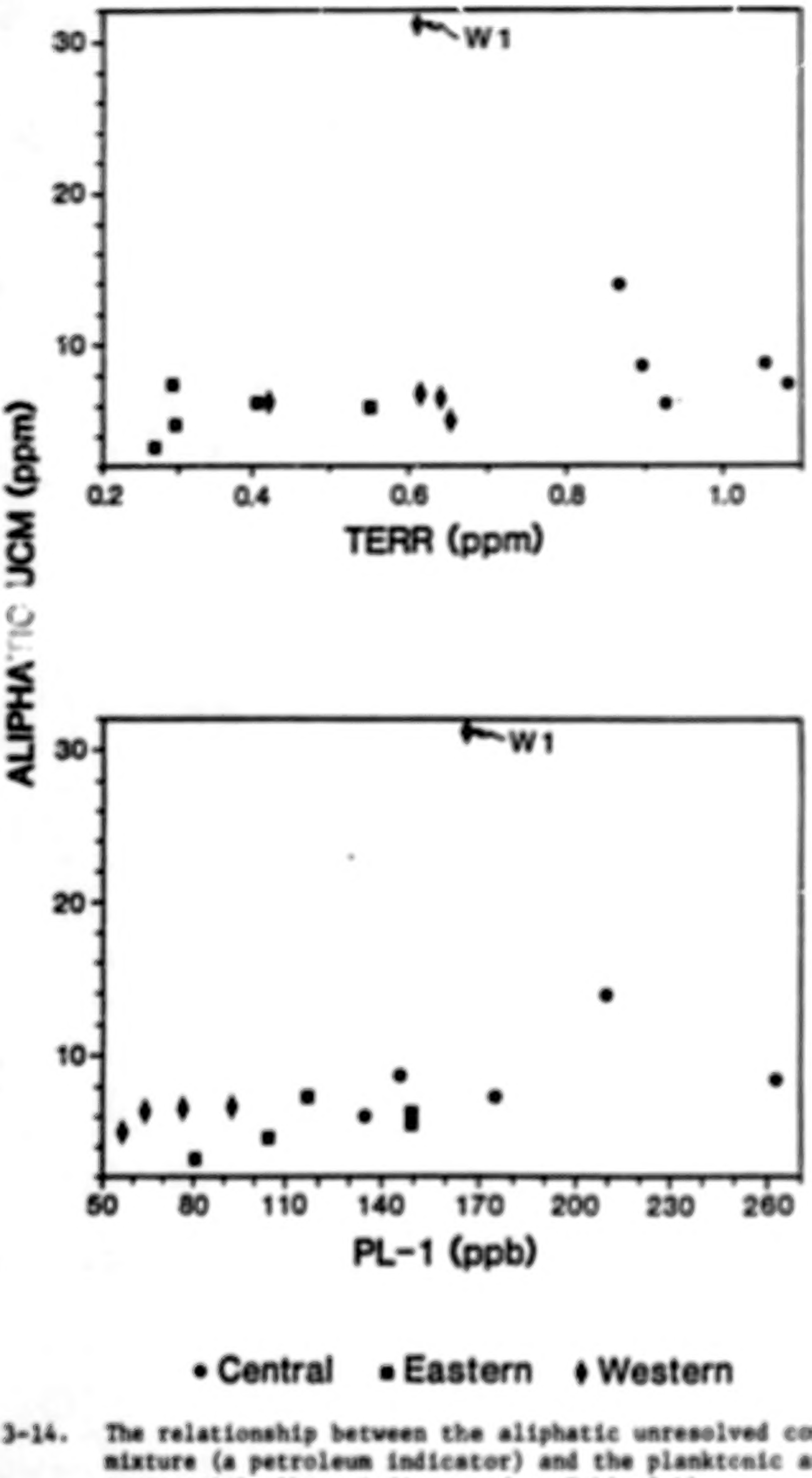


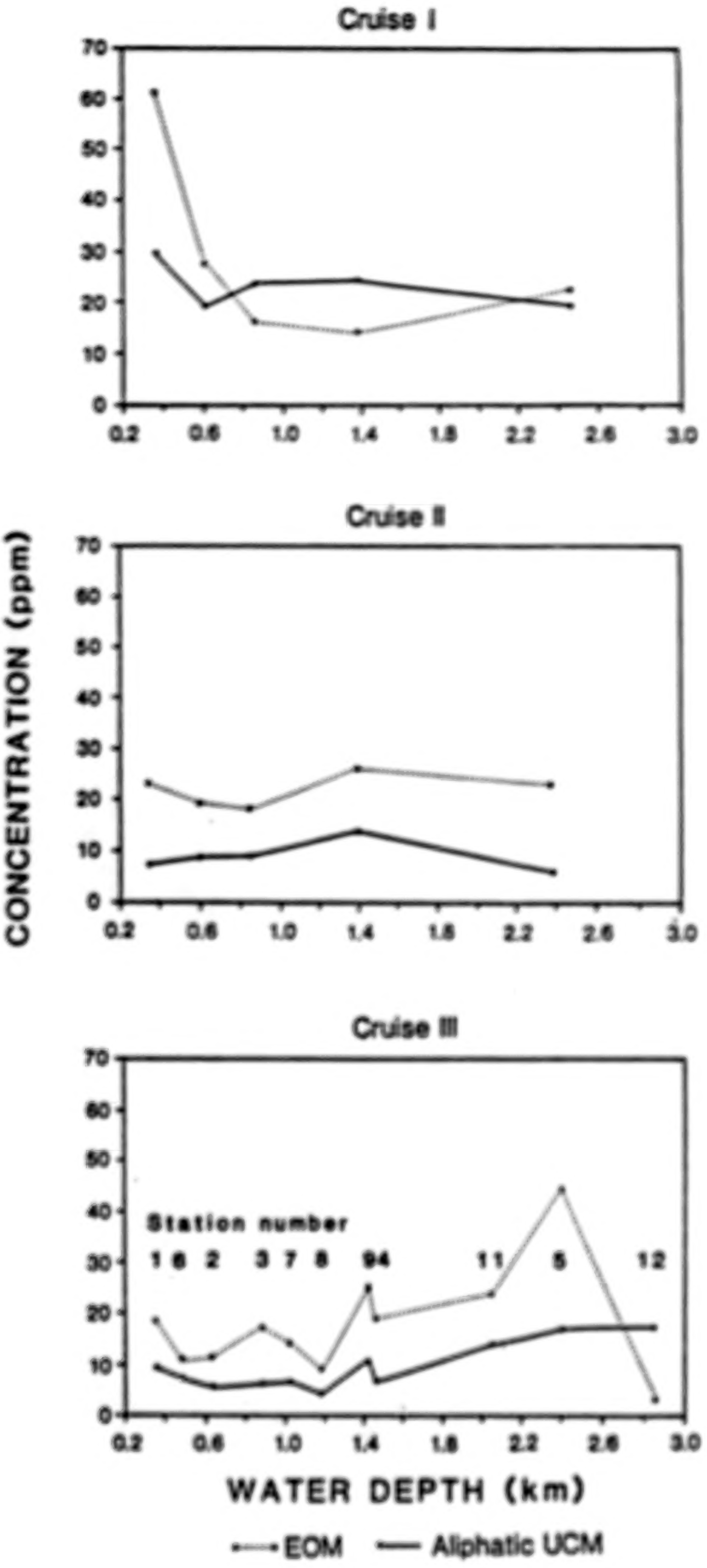
Figure 3-14. The relationship between the aliphatic unresolved complex mixture (a petroleum indicator) and the planktonic and terrestrial alkane indicator (see Table 3-3).

true. However, extensive natural hydrocarbon seepage has been documented on the Gulf of Mexico continental slope, further supporting natural seepage as a major petroleum hydrocarbon input to Gulf of Mexico continental slope sediments. It is also evident that some fraction of the petroleum hydrocarbons are transported to the slope by river/land-derived particles most likely by secondary movement such as slumps and/or turbidity flows.

3.2.2.3 Temporal Variations

Cruises I (November 1983), II (April 1984), and III (November 1984) sampled the Central Transect in an attempt to document variability between samplings. The distribution of EOM and aliphatic UCM during these three sampling cruises is shown in Figure 3-15. On an average, the aliphatic UCM, a petrogenic indicator, was highest on Cruise I (Fig. 3-15, Table 3-1). UCM concentrations during Cruise II and at the shallower stations (<1500 m) of Cruise III, were similar. During Cruise III the UCM was markedly higher at stations deeper than 1500 m than had been observed on Cruises I and II. Molecular-level indicators were similar along the Central Transect during Cruises I and II (Figs. 3-16 and 3-17), but substantial differences were also observed on Cruise III at depths greater than 1500 m.

Significant variability with depth was observed during Cruise III sampling. Shallower stations (<1500 m) during Cruise III were lower in hydrocarbons than the two previous samplings, which suggests dilution by inorganic material. Compared with Cruises I and II, terrestrial hydrocarbons were significantly reduced over the entire transect. The deepest stations (>1500 m) on Cruise III had elevated levels of petroleum hydrocarbons. This is substantiated by the hydrocarbon-source parameters previously discussed (Figs. 3-16 and 3-17). Examination of carbon preference index (PI) distributions and gas chromatograms suggest the presence of relatively fresh petroleum hydrocarbons, probably from oil seepage, at the deepest stations (Fig. 3-18). Station C7 also had a low CPI, suggesting anomalously high petroleum hydrocarbons. These differences between samplings most likely represent the patchiness of hydrocarbon distributions rather than a temporal change such as an influx



Cruise I

Cruise II

Cruise III

Figure 3-15. Variation in extractable organic matter (EOM) and the aliphatic unresolved complex mixture (UCM) during three samplings of the central transect.

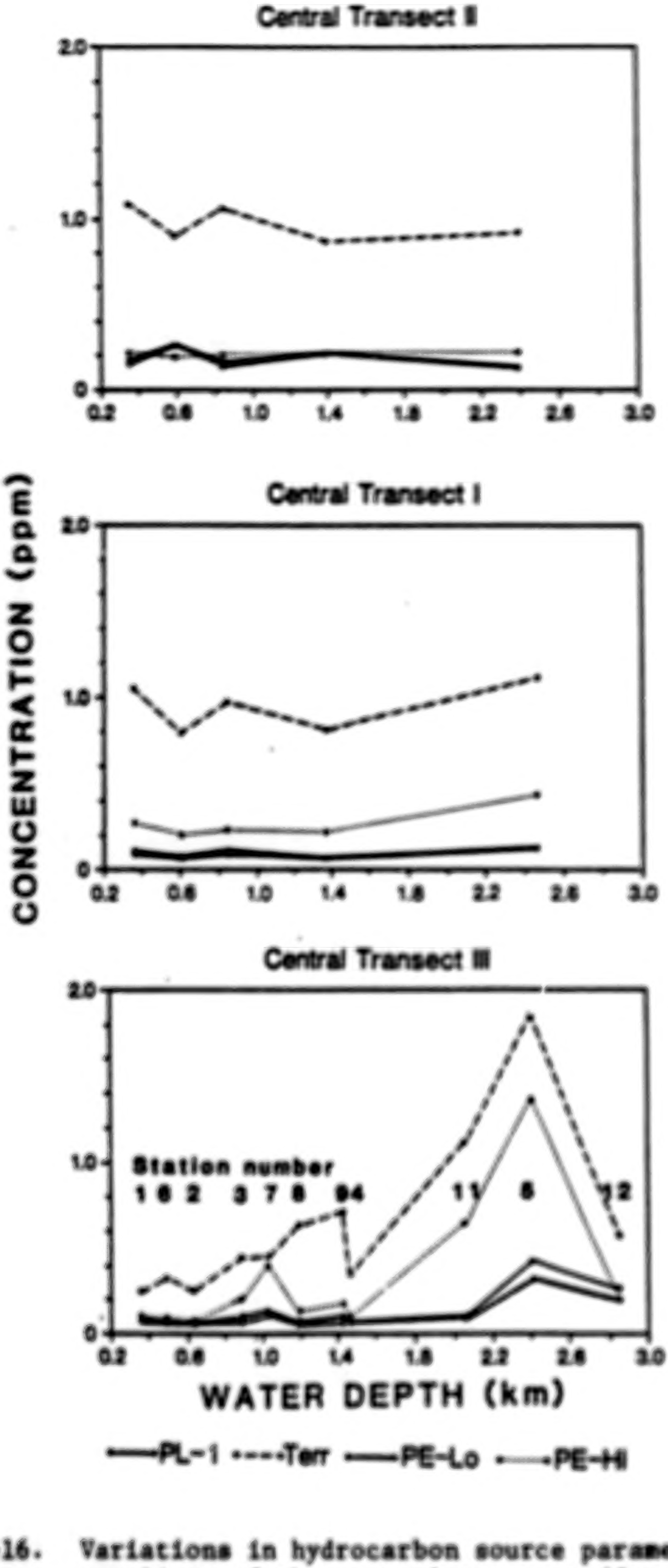


Figure 3-16. Variations in hydrocarbon source parameters during three samplings of the central transect (for definition of source parameters see Table 3-3).

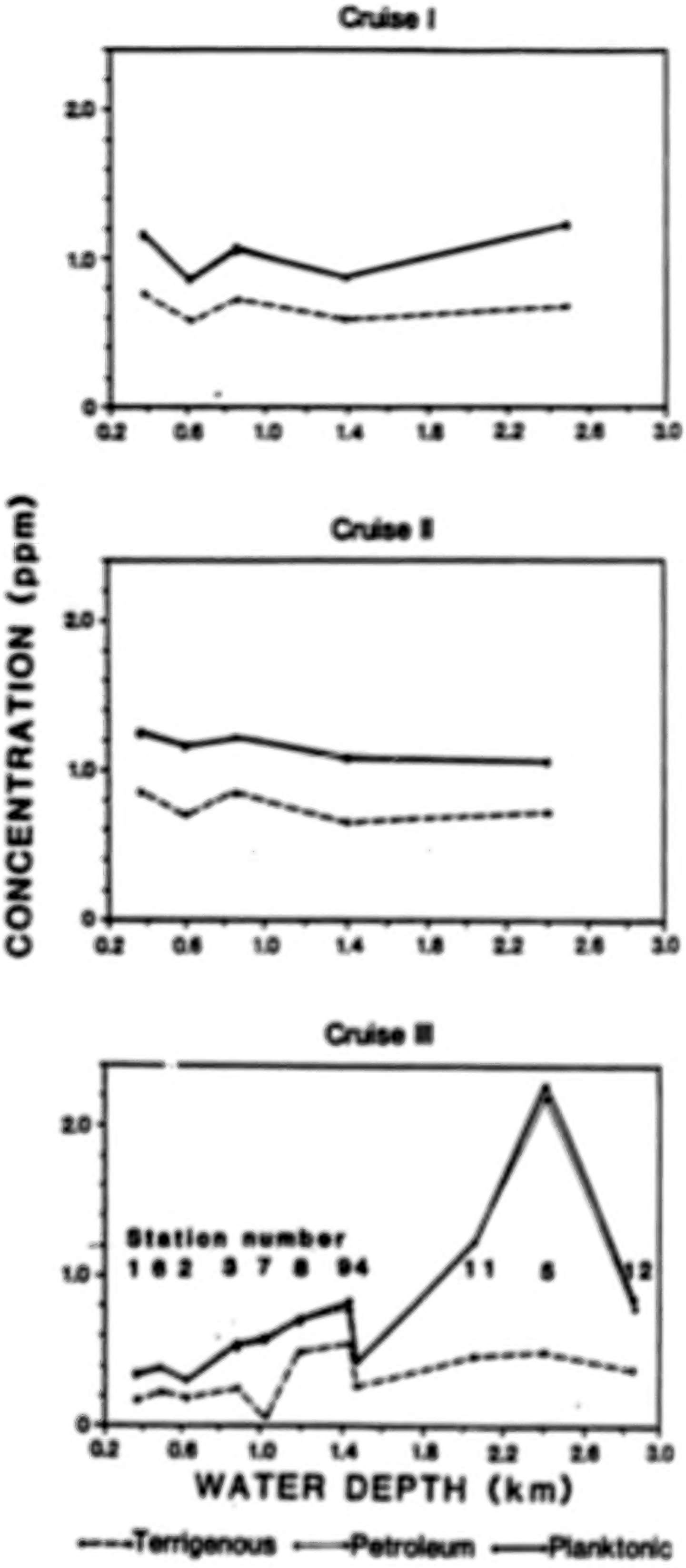


Figure 3-17. Variation in plankton, terrestrial and petroleum hydrocarbons during three samplings of the central transect presented as a cumulative concentration (for an explanation see Figure 3-12).

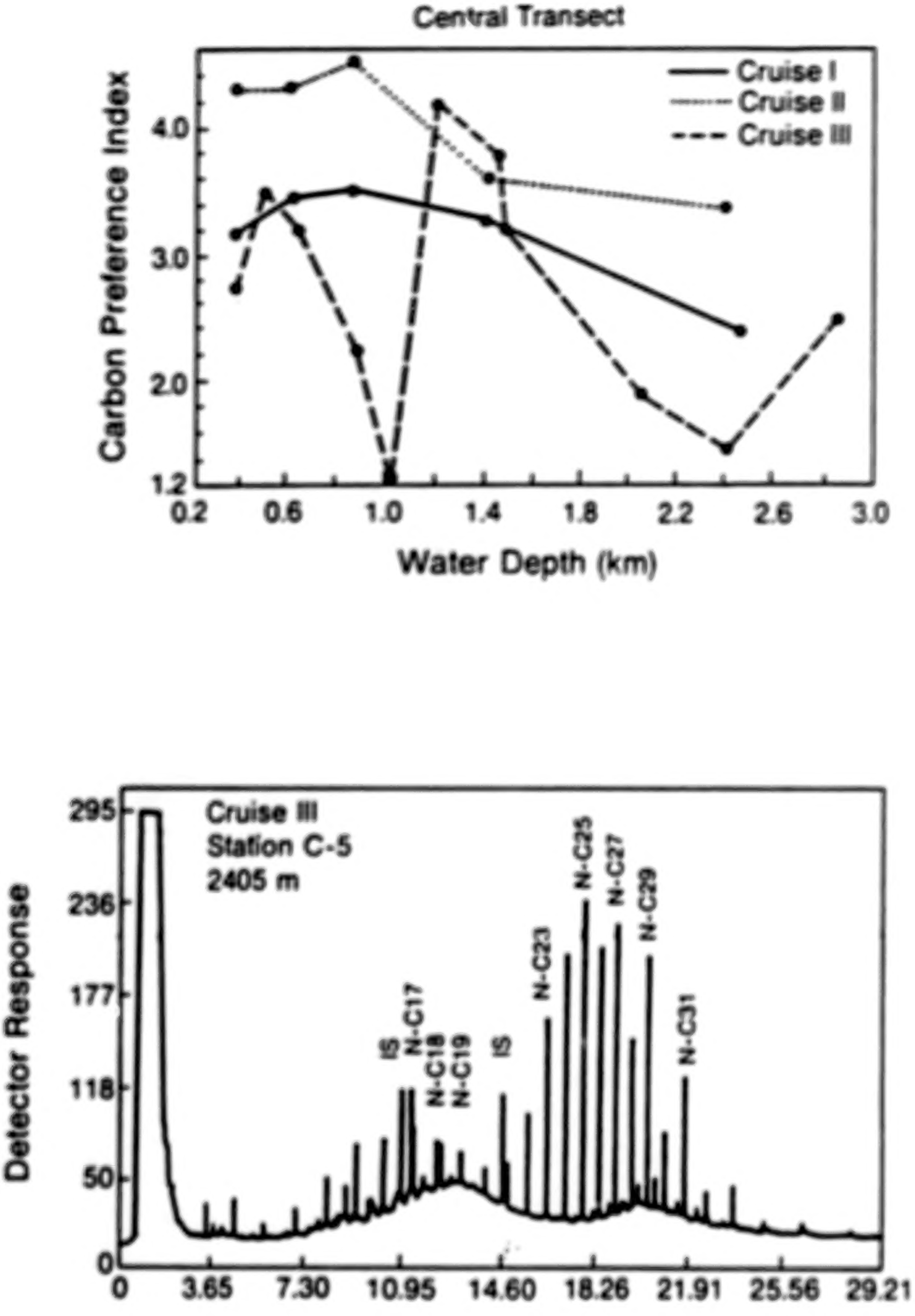


Figure 3-18. Variation in the carbon preference index (CPI) as a function of depth along the Central Transect during Cruise III and a representative fused silica gas chromatogram of the aliphatic hydrocarbons from Station C5, Cruise III (CPI = $[\Sigma n\text{-}C_{23,25,27,29,31}] / [\Sigma n\text{-}C_{24,26,28,30,32}]$).

of hydrocarbons. Station C7 was later documented to have oil seep-community organisms in residence.

3.2.2.4 Variability Along Isobaths

Cruise V in the eastern Gulf of Mexico occupied stations along three isobaths to assess lateral variation in the measured parameters. Hydrocarbon parameters are summarized in Table 3-4. Bulk and molecular-level hydrocarbon parameters were low during this sampling and represent some of the lowest values measured during this study (Table 3-1). Therefore, the variability observed along this transect is most likely a maximum. Cruise V sampling sites were also chosen to contrast sediment texture which will also contributes to the high degree of variability of hydrocarbon parameters observed. (Detailed sediment texture data for Cruises I-V may be found in Appendix B-2.) The aliphatic UCM and total EOM varied by factors of 1.7 to 7.6 at a given depth. Molecular-level indicators (i.e., individual component sums) varied by a factor of 2.0 to 7.6 along a given isobath. This data suggests that, at these low concentrations, hydrocarbons are as variable along isobaths as they are with water depth. This again emphasizes the patchy nature of hydrocarbon distributions. Bulk sediment parameters varied by as much as a factor of 3 along an isobath illustrating the variations observed in sediment texture.

Samples along isobaths in the central and western Gulf were also taken. Stations from Cruises I, II, III and IV at ~350 m are compared in Table 3-5. The variability in hydrocarbon parameters reflecting terrestrial input show the greatest variation, i.e., as much as 40 fold. The planktonic indicators are also highly variable, most likely due to dilution with terrestrially sourced material. Bulk parameters such as clay content varied by a factor of 2 and sand content varied from 0.5 to 36.6% at these six locations. These variations reflect the substantial influence of river/land derived material. Three samples from Cruise IV along the 550- and 750-m isobath were relatively uniform. The lateral extent covered at these isobaths was small relative to the 350-m isobath sampling. Bulk parameters were also uniform along these two isobaths.

Table 3-4. Variability in hydrocarbon parameters along isobaths - eastern Gulf of Mexico.

Depth (m) Parameter	Variable Ranges 342-383 n=4	 619-630 n=6	 819-859 n=5
Total EOM (ppm)	5.8 - 13.4 (9.7)[1]	4.7 - 9.9 (6.8)	4.9 - 8.2 (5.8)
Aliphatic (ppm)	0.7 - 5.0 (3.0)	0.5 - 3.8 (1.8)	0.7 - 3.1 (1.7)
PL-1[2] (ppb)	11.5 - 94.1 (54.3)	8.1 - 59.1 (29.9)	6.9 - 44.8 (23.4)
TERR[2] (ppb)	36.0 - 74.0 (55.9)	55.9 - 119.8 (78.6)	23.4 - 147.5 (121.6)
PE-Lo[2] (ppb)	13.3 - 100.7 (56.2)	13.5 - 39.8 (21.1)	11.0 - 27.3 (18.8)
PE-Hi[2] (ppb)	14.4 - 30.3 (22.3)	20.4 - 53.1 (33.1)	17.5 - 77.6 (48.6)
Terrigenous[3] (ppb)	21.6 - 49.8 (33.6)	24.0 - 66.7 (45.4)	5.9 - 99.5 (72.8)
Petroleum[3] (ppb)	33.5 - 118.3 (78.5)	34.6 - 67.9 (54.3)	28.5 - 103.5 (67.4)
Planktonic[3] (ppb)	0.0 - 2.8 (0.7)	0.0 - 20.1 (9.5)	0.0 - 17.5 (7.3)

[1] Average.

[2] PL-1 = Σn-$C_{15, 17, 19}$ and Pristane; TERR = Σn-$C_{25, 27, 29, 31}$; PE-Lo = Σn-$C_{16, 18, 20}$ and Phytane; PE-Hi = Σn-$C_{24, 26, 28, 30}$.

[3] Terrigenous = (TERR) - (PE-Hi); Petroleum = (PE-Lo) + (PE-Hi); Planktonic = (PL-1) - (PE-Lo).

Table 3-5. Variability in hydrocarbon parameters along isobaths - west/central Gulf of Mexico.

Depth Parameter	298-371[1] n=6	547-550[2] n=3	748-759[3] n=3
Total EOM (ppm)	15.9 - 61.3 (34.5)	17.4 - 23.9 (20.6)	17.0 - 57.9 (30.9)
Aliphatic UCM (ppm)	6.0 - 31.4 (15.6)	6.9 - 7.9 (7.6)	5.6 - 11.9 (8.4)
PL-1 (ppb)	36.3 - 174.9 (121.8)	47.4 - 65.3 (56.4)	50.0 - 68.0 (59.9)
TERR (ppb)	93.4 - 1082.8 (546.7)	109.8 - 273.1 (201.2)	169.7 - 180.5 (176.3)
PE-Lo (ppb)	36.2 - 154.5 (100.3)	39.1 - 52.5 (43.7)	43.4 - 48.9 (45.2)
PE-Hi (ppb)	70.9 - 279.7 (172.2)	80.6 -121.9 (99.4)	48.0 - 96.6 (64.8)
Terrigenous (ppb)	22.5 - 860.6 (374.5)	29.2 - 252.2 (101.7)	83.9 - 130.8 (111.5)
Petroleum (ppb)	123.3 - 388.0 (127.4)	119.7 - 161.5 (143.2)	91.4 - 140.0 (110.1)
Planktonic 9ppb)	0.1 - 57.7 (21.5)	4.0 - 26.2 (12.7)	6.6 - 19.1 (14.7)

[1] Cruises I, II and III, Stations E1 and W1; Cruise IV, Stations WC1 and WC2.

[2] Stations WC2, WC4, WC8.

[3] Stations WC3, WC9, WC10.

Detailed sediment hydrocarbon data for each station sampled during Cruises I-V may be found in Appendices B-4, B-5, and B-6.

3.2.2.5 Topographic Features

One set of paired stations (WC-11 and WC-12) were taken to compare topographic differences. In this pairing both stations had equivalent depths (1200 m), WC-11 was a topographic convexity, whereas WC-12 was a topographic concavity. The sediment sample at the convexity was elevated in petroleum hydrocarbons (Table 3-6). This difference cannot simply be ascribed to topographic differences and more likely suggests that seepage has occurred at Station WC-11. More detailed studies will need to be performed to understand the relationship between hydrocarbons and topographic expressions.

3.2.2.6 Relationship to Bulk Sediment Parameters

In general, the highest aliphatic hydrocarbon concentrations were associated with the more clay sediments rich in organic carbons. To understand more fully sedimentological relationships it is most effective to consider the three primary hydrocarbon sources individually since their distribution may be controlled by different factors. The data must also be considered in the context of the hypothesis the sampling was designed to test, i.e., areal, temporal and water depth dependence. The terrigenous or land-derived component sometimes correlated with grain size distribution changes within a given sampling period, however, when the data were considered as a complete set, these trends were not readily apparent (Fig. 3-19). This is most likely due to the ratio of clay to terrigenous organic matter changing with time and location. Detailed sediment data from Cruises I-V are found in Appendix B-2.

Among the samples, the Cruise II Central and Cruise IV Western/Central samples correlated least with grain size. This may be due to a substantial petroleum input to the TERR indicator that is independent of the river. It is also probable that the seaward distance the material is transported and the composition of the transported material vary with time. The largest range in clay content was observed during Cruise II

Table 3-6. Comparison of sediment hydrocarbon parameters at two different topographic settings (for definitions of hydrocarbon parameters see Tables 3-3 and 3-4).

Depth (m)	WC-11 Topo-Hi 1226	WC-12 Topo-Low 1236
Total EOM (ppm)	18.9	17.1
Aliphatic UCM (ppm)	81.4	4.2
PL-1 (ppb)	266.6	67.5
TERR (ppb)	3068.3	182.6
Petro-Lo (ppb)	248.2	45.7
Petro-Hi (ppb)	852.7	44.9
Terrestrial (ppb)	2233.7	137.7
Planktonic (ppb)	18.4	21.8
Petroleum (ppb)	1100.9	90.6

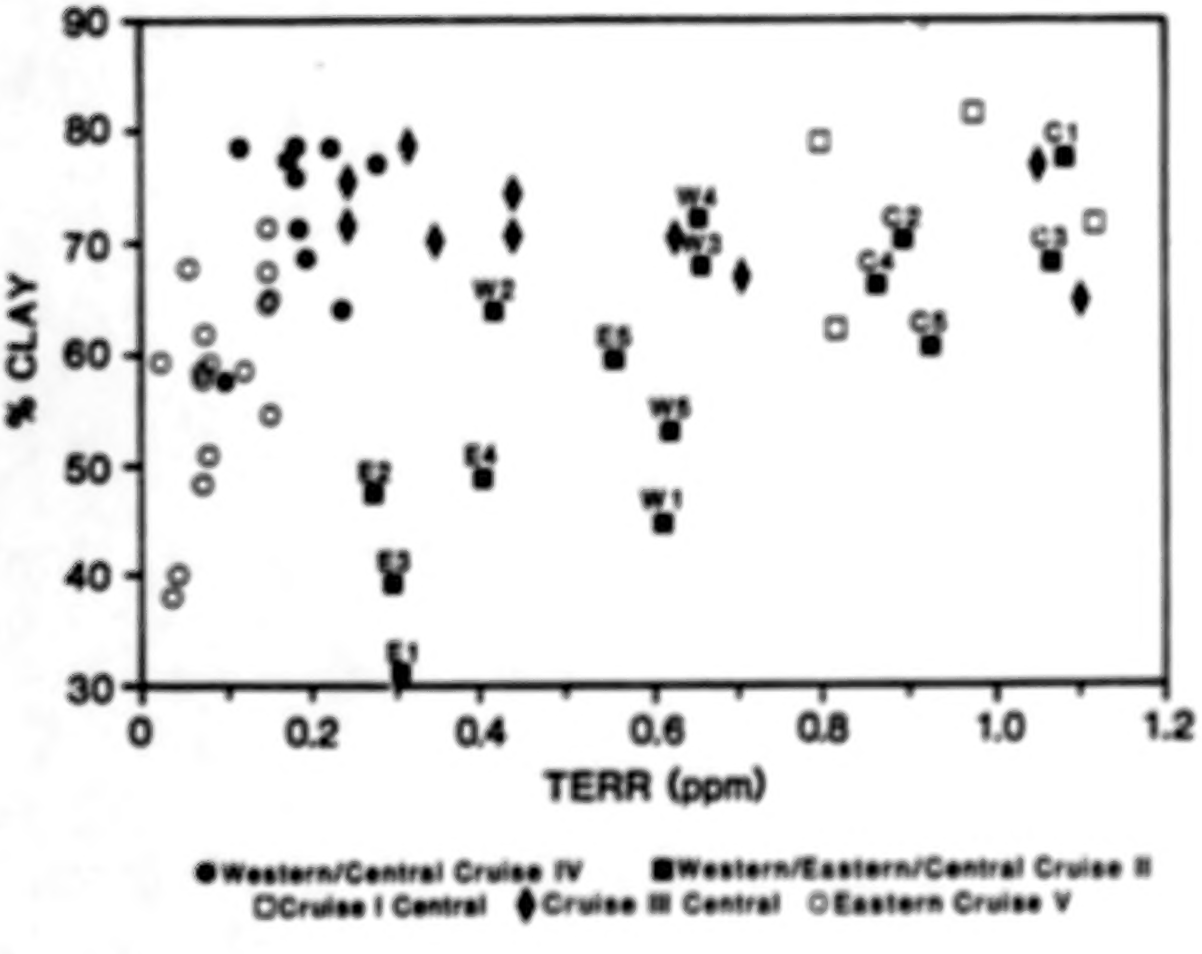


Figure 3-19. The relationship between a terrestrial hydrocarbon indicator and the clay content of the sediment.

when the Western, Central and Eastern Transects were sampled (Fig. 3-20). In this case a positive correlation with clay content and a negative correlation with sand content is readily apparent; however, within a given transect the correlation is less striking. The correlation of the terrigenous indicator with grain size supports the premise that these n-alkanes represent riverine or land-derived material. In general the relative importance of riverine material between geographical areas can be estimated though variability within a given area, i.e., along a transect, can be substantial.

The petroleum indicators were generally independent of grain size, though as previously mentioned some component of the petroleum is related to river-associated particles (Fig. 3-21). This river influence can be seen most clearly on the Eastern Transect where the PE-Lo indicator generally increases with increasing clay content. In contrast the aliphatic UCM is apparently independent of clay content (Fig. 3-21), which confirms a dual source for petroleum hydrocarbons. Phytoplankton-derived hydrocarbons did not correlate with grain size.

3.2.2.7 Aromatic Hydrocarbons

Sediment aromatic hydrocarbons were below the detection limit (~5 ppb) at all locations sampled. The presence of aromatic hydrocarbons at low concentrations was inferred by total scanning fluorescence analyses, supporting the conclusion that a low level petroleum input is present at all locations sampled.

3.3 CARBON ISOTOPES

3.3.1 SEDIMENTS

The carbon isotopic composition of sedimentary organic matter for all five cruises is summarized in Figure 3-22. Isotopic data confirms the previously inferred influence of river-borne terregenous material on the Gulf of Mexico continental slope. Though there are numerous complicating factors, in general a more negative carbon isotopic composition suggests greater land influence. Terrestrially sourced organic material, delta ^{13}C

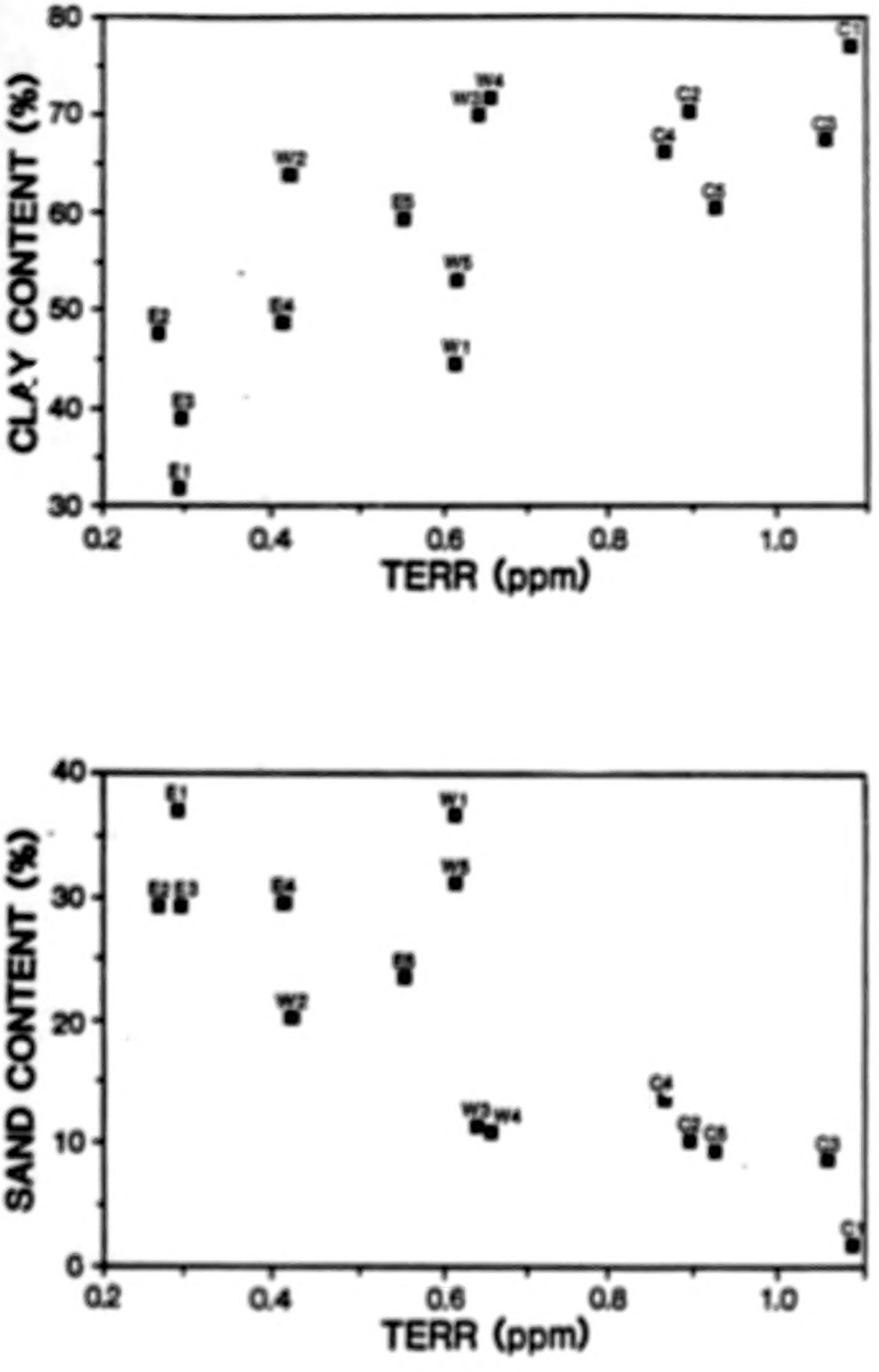


Figure 3-20. The relationship between a terrestrial hydrocarbon indicator and the clay and sand content of the sediment during Cruise II.

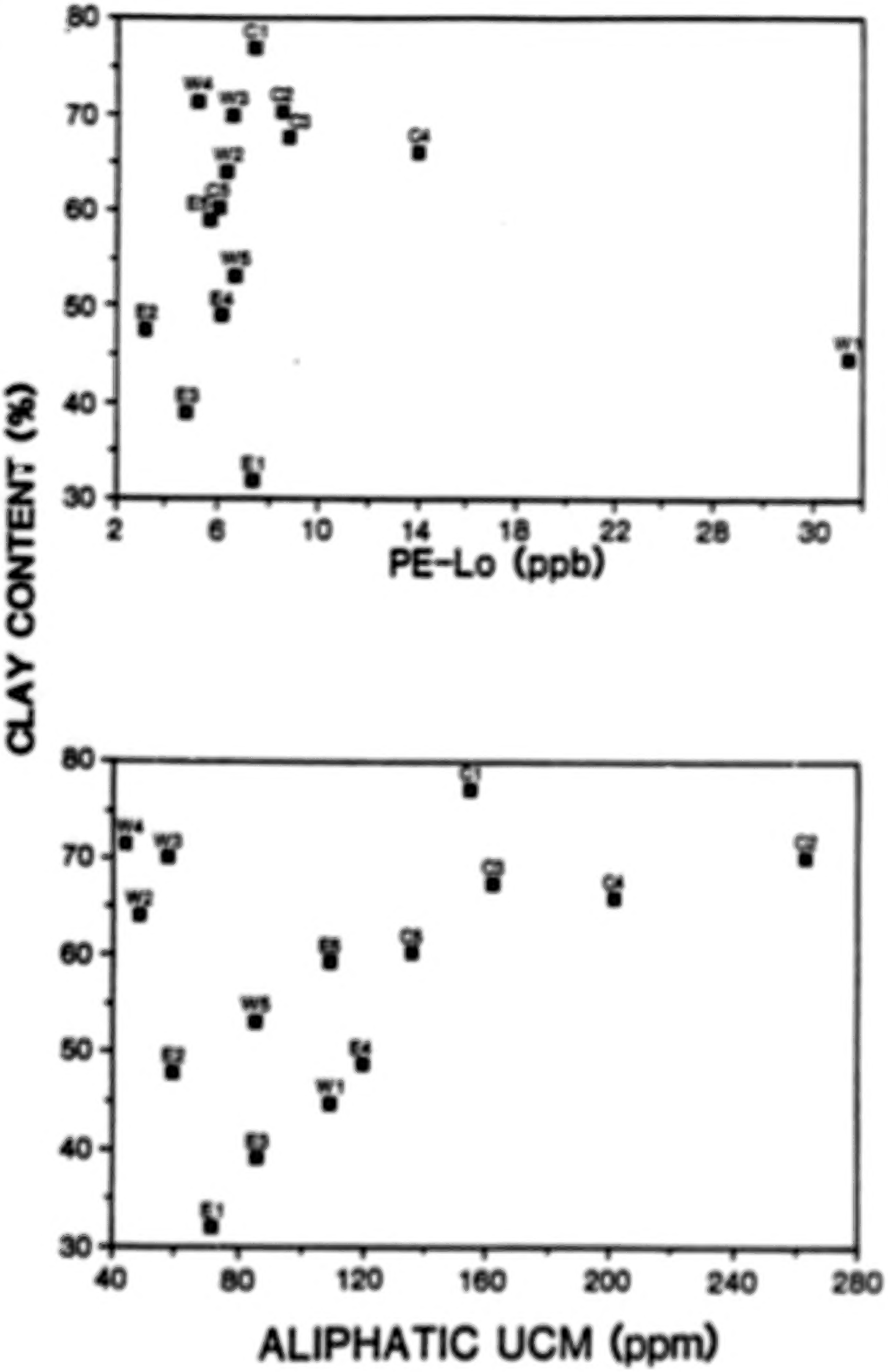


Figure 3-21. The relationship between two petroleum hydrocarbon indicators and the clay content of the sediment during Cruise II.

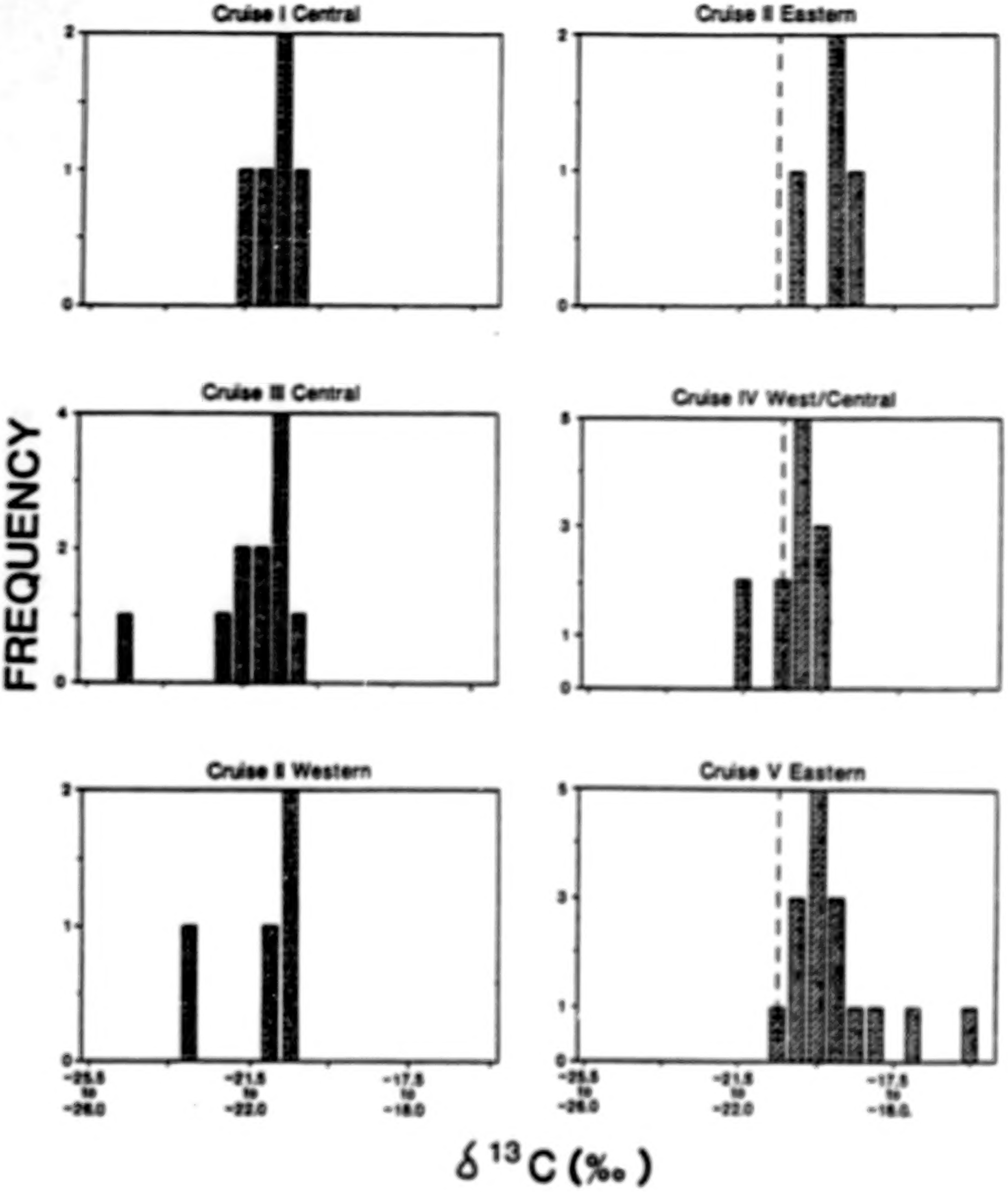


Figure 3-22. Summary of the carbon isotopic composition of sedimentary organic matter from all five cruises ($\delta^{13}C$ in $^{0}/oo$, vs. Pee Dee Belemite).

varies from approximately -25 to -28° °/°°, while planktonic-derived carbon delta ^{13}C varies from approximately -16 to -21 °/°°. As can be seen the average delta ^{13}C of sedimentary organic material is most positive at the eastern stations, most negative at the Central and Western sampling sites. This trend suggests an increased influence of planktonic material at the eastern sites. In general the average delta ^{13}C suggests a substantial planktonic contribution to the bulk organic matter, whereas the hydrocarbons are generally dominated by terrestrial sources.

3.3.2 ORGANISMS

Stable carbon isotopes have been widely used in marine research to trace the flow of carbon in ecosystems and the biogeochemical systems (Parker 1964, Sackett 1964, Calder and Parker 1968, Haines 1976, DeNiro and Epstein 1978, Haines and Montague 1979, Fry and Parker 1979, Fry 1981, Gearing et al. 1984). Several assumptions are inherent in their use including (1) a relatively constant isotopic composition of organic carbon produced by each plant source, (2) an unchanging isotopic ratio in plant carbon as it decomposes and is broken down into detritus, and (3) little or no isotopic fractionation between consumer and its carbon supply. Gearing et al. (1984) have recently provided an excellent review of the carbon isotopic literature relating to these assumptions.

The first assumption is generally applicable within a few parts per thousand for marine plankton. Isotopic variability in marine phytoplankton has been correlated with species composition, temperature, water masses, latitude, and delta ^{13}C of the inorganic carbon that is fixed. Little isotopic fraction is generally observed in the aerobic decomposition of organic matter in seawater. They observed an overall pattern of increasing carbon isotope ratios with trophic levels, progressing from diatoms (-20.3 °/°°), to zooplankton (-19.8 °/°°), meiofauna (-19.5 °/°°), non-carnivorous macrofauna (-18.6 °/°°), and benthic predators (-16.6 °/°°). Similar patterns have been documented in other studies and support an isotopic shift of a few parts per thousand to more positive values with increasing trophic level. The organism tissue isotopic data for all five cruises is summarized in Figures 3-23 and 3-24.

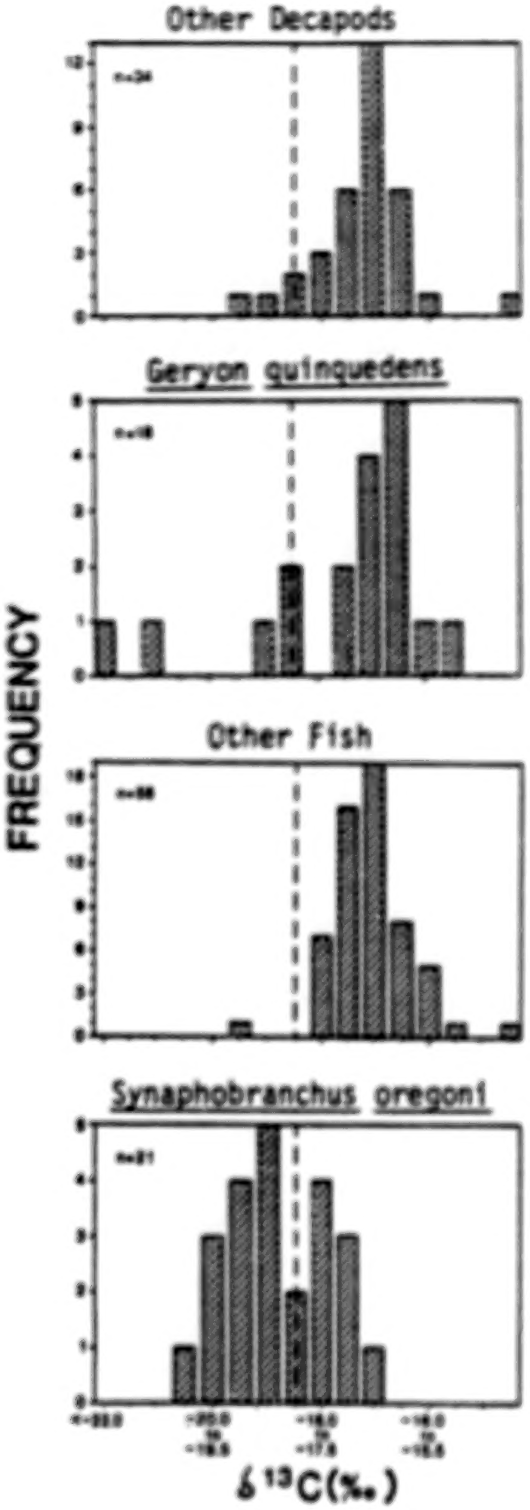


Figure 3-23. Summary of the carbon isotopic composition of organism tissues by organism type ($\delta^{13}C$ in ⁰/oo vs. PPB).

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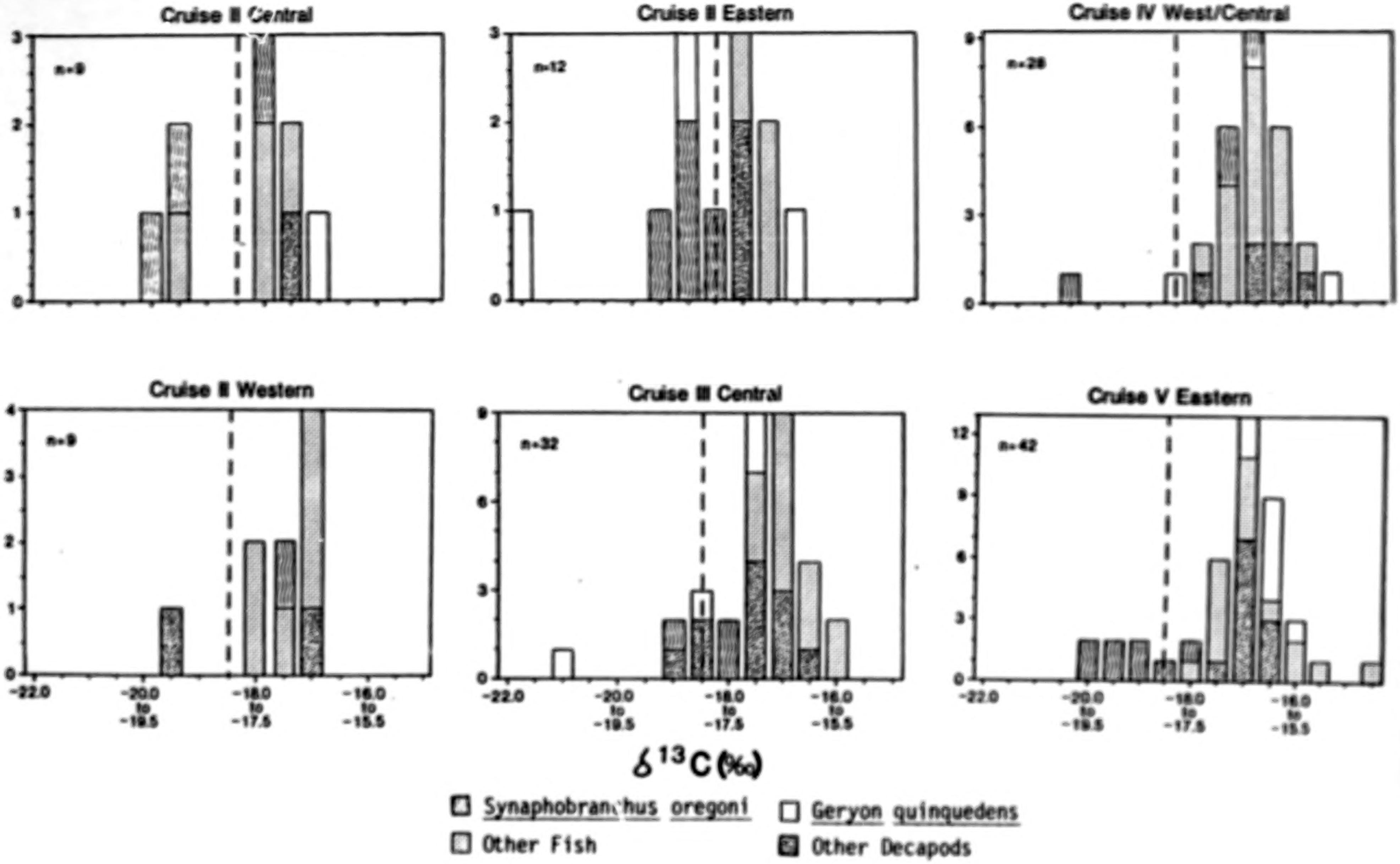

Figure 3-24. Summary of the carbon isotopic composition of organism tissues by transect and organism type for all five cruises ($\delta^{13}C$ in $^{0}/oo$ vs. Pee Dee Belemite).

Detailed carbon isotope data for organisms for each station sampled may be found in Appendix B-3.

3.4 ORGANISM HYDROCARBONS

Hydrocarbon levels in Gulf of Mexico slope organisms are highly variable. Detailed hydrocarbon data for organisms sampled from Cruises I-V are found in Appendices B-7, B-8, and B-9. Total resolved alkanes in samples from Cruises I, II and III varied from non-detectable to >8000 ppb (Figure 3-25). Due to the variety of organisms and organ types analyzed, trends in variations as a function of location, water depth, and time of sampling are difficult to discern. The species collected and analyzed were highly variable thus making direct comparisons difficult if not impossible. No trends in hydrocarbon distributions were evident as a function of any taxonomic group of organisms evaluated (3-25). Of the organisms analyzed, decapods had the lowest incidence of hydrocarbon occurrence in muscle tissue (Table 3-7). More than ~75% of the fish muscle tissues analyzed contained detectable hydrocarbons. In the sampling provided by this study there were no detectable hydrocarbons in several species, primarily shrimp (Table 3-8). The sampling is often limited to a single individual and therefore cannot properly represent the entire population.

Tissue hydrocarbons were generally dominated by pristine, n-C^{17}, n-C^{15} and n-C^{19} (Figs. 3-26 to 3-28). These hydrocarbons are predominantly planktonic in origin. In general n-C^{16}, n-C^{18} and phytane were also present. These may have a petroleum source but due to the low concentrations observed their source is not clear. It is also possible that this range of n-alkanes has a bacterial source. A few organisms also contained measurable amounts of higher molecular weight petroleum and plant biowax hydrocarbons (Table 3-9, Figs. 3-29 and 3-30). These organisms were all collected at the Central Transect except for one shrimp at Station E3 during Cruise II that contained primarily petroleum hydrocarbons. The presence of the plant biowaxes suggests that these organisms have acquired the hydrocarbon signature of the sediments. These hydrocarbons presumably reside in sediments and not in the water column at these water depths. In two organisms the plant biowaxes were detected in

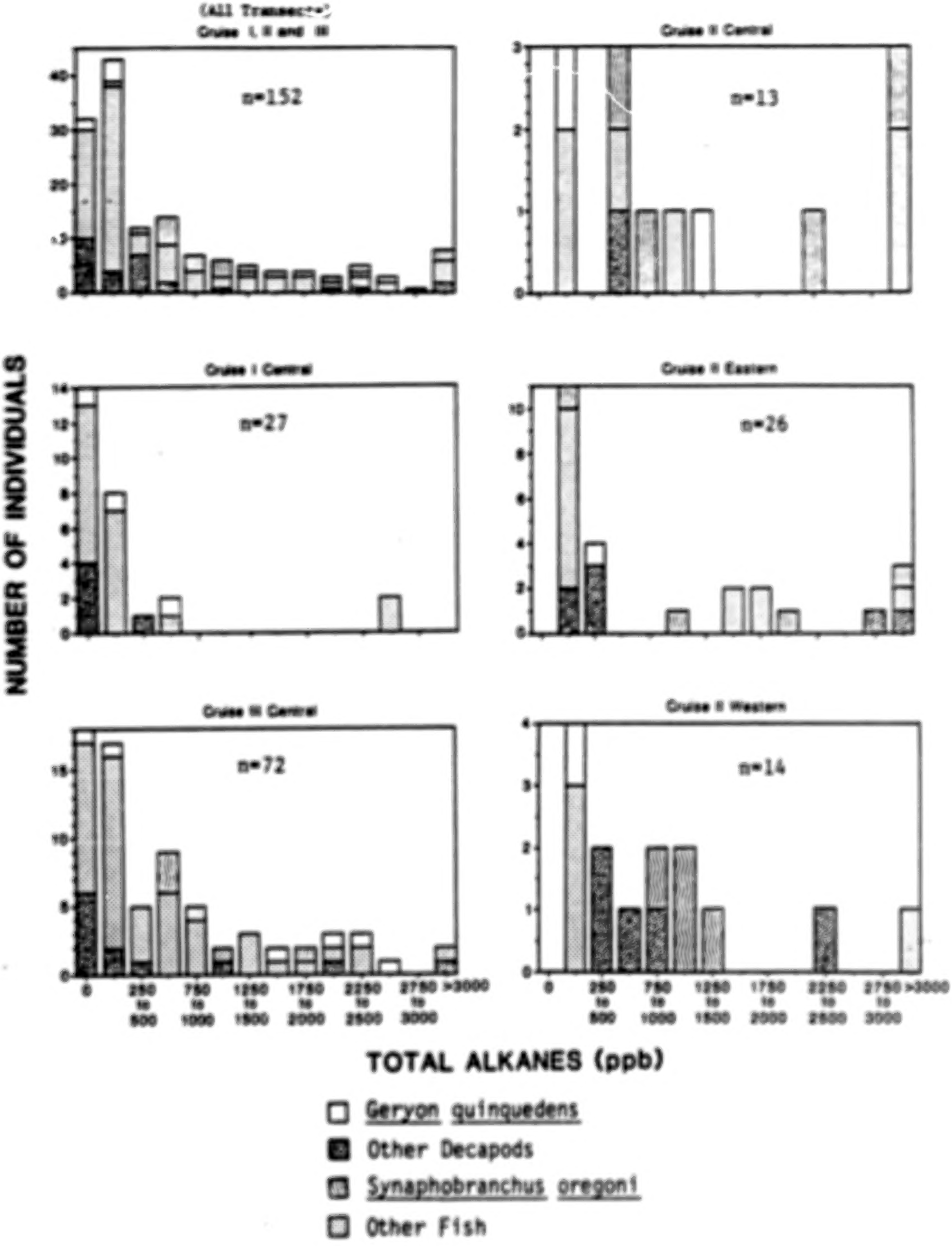

Figure 3-25. Summary of the total alkane concentration in organism tissues for Cruises I, II and III.

Table 3-7. Summary of the incidence of detectable hydrocarbons in organisms muscle tissue (Cruises I-V).

Type of Organisms	No. of Species	No. of Individuals Analyzed	No. of Individuals Hydrocarbon Free
Fishes	28	80	21 (26.3%)*
Eels	2(?)	17	3 (17.6%)
Crabs	4	19	11 (57.9%)
Shrimp	18	40	25 (62.5%)

*Percent of individuals analyzed.

Table 3-8. Species in which no tissue hydrocarbons were detected in organism in the present study.

Cruise	Station	No. of Individuals Analyzed	Species	Type of Organism
5	E3D E2E E2B	3	*Munida valida*	Shrimp
4	WC8	1	*Hymenopenaeus robustus*	Shrimp
1	C2	1	*Acanthephyra armata*	Shrimp
1	C3	1	*Benthesicymus bartletti*	Shrimp
3	C6	1	*Nephropsis aculeata*	Shrimp
3	C1	1	*Parapenaeus longirostris*	Shrimp
3	C2	1	*Plesionika holthuisi*	Shrimp
4	WC6	1	*Merluccius albidus*	Fish
5	E2D	1	*Metanephrops binghami*	Shrimp
1	C4	1	*Cataetyx* sp.	Fish
5	E1	1	*Pocilopsetta beani*	Shrimp
4	WC5	1	*Polycheles typhlops*	Lobster

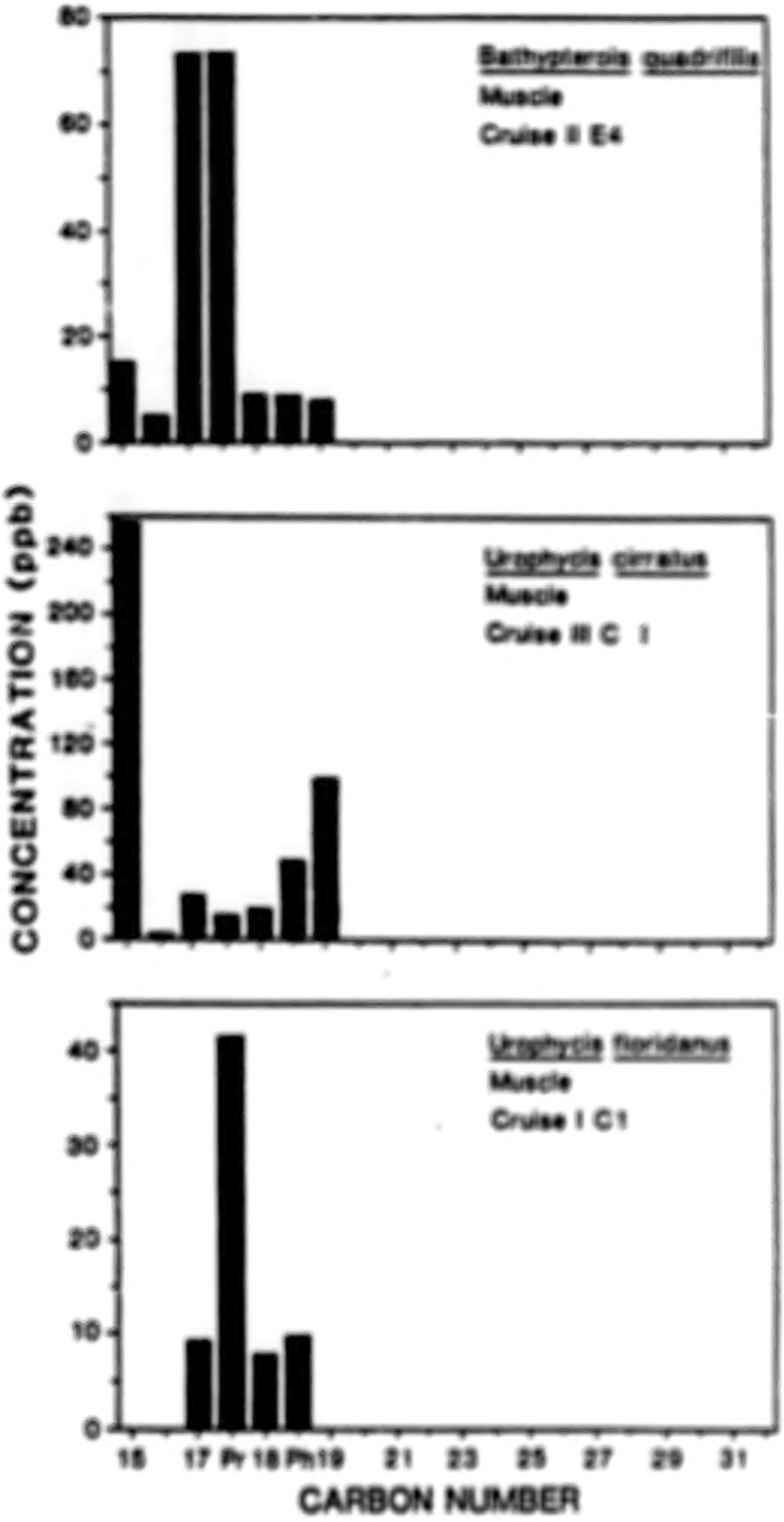

Figure 3-26. Selected examples of alkane distributions in fish tissues (Pr = pristane, Ph = phytane).

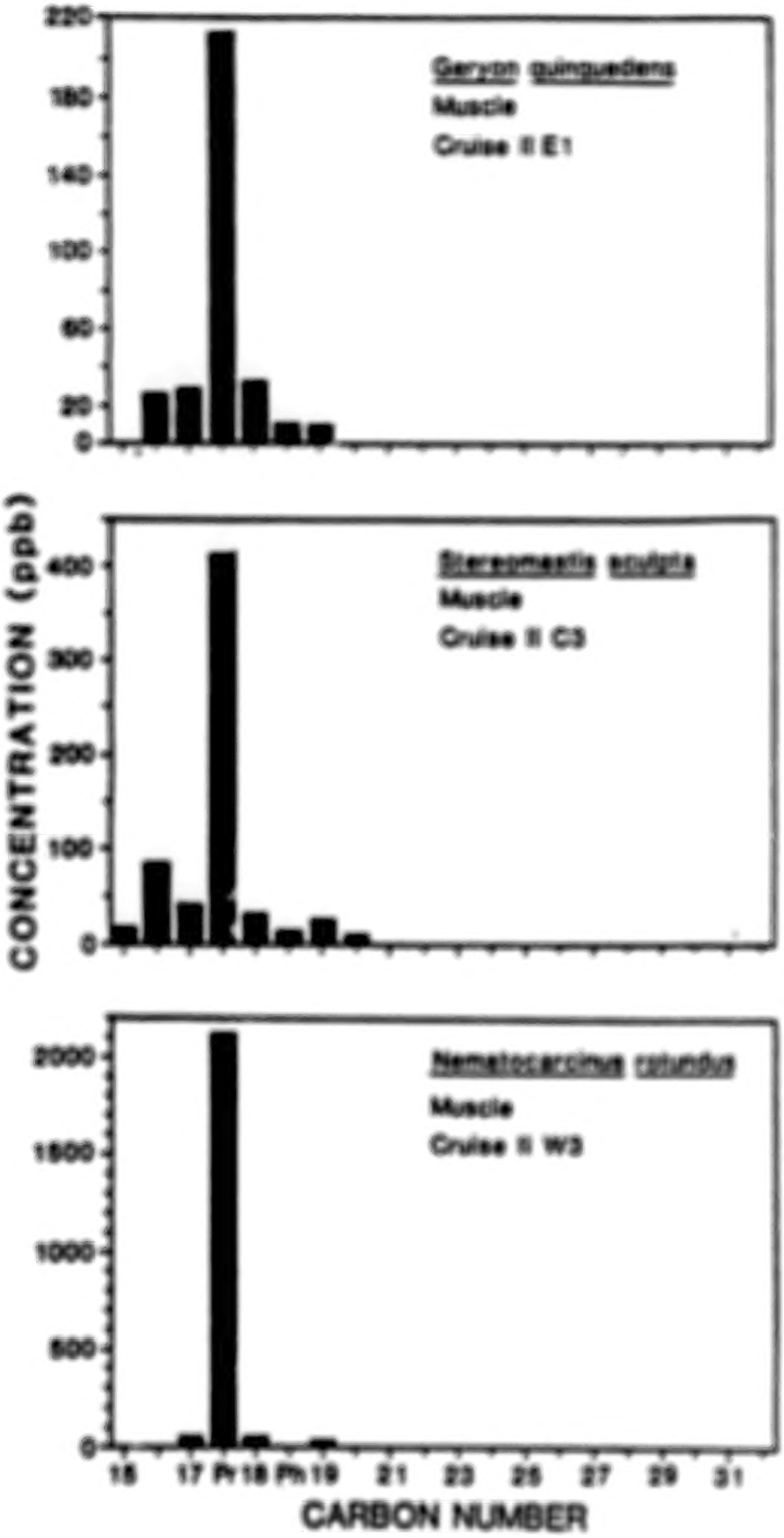

Figure 3-27. Selected examples of alkane distributions in crab and shrimp tissues (Pr = pristane, Ph = phytane).

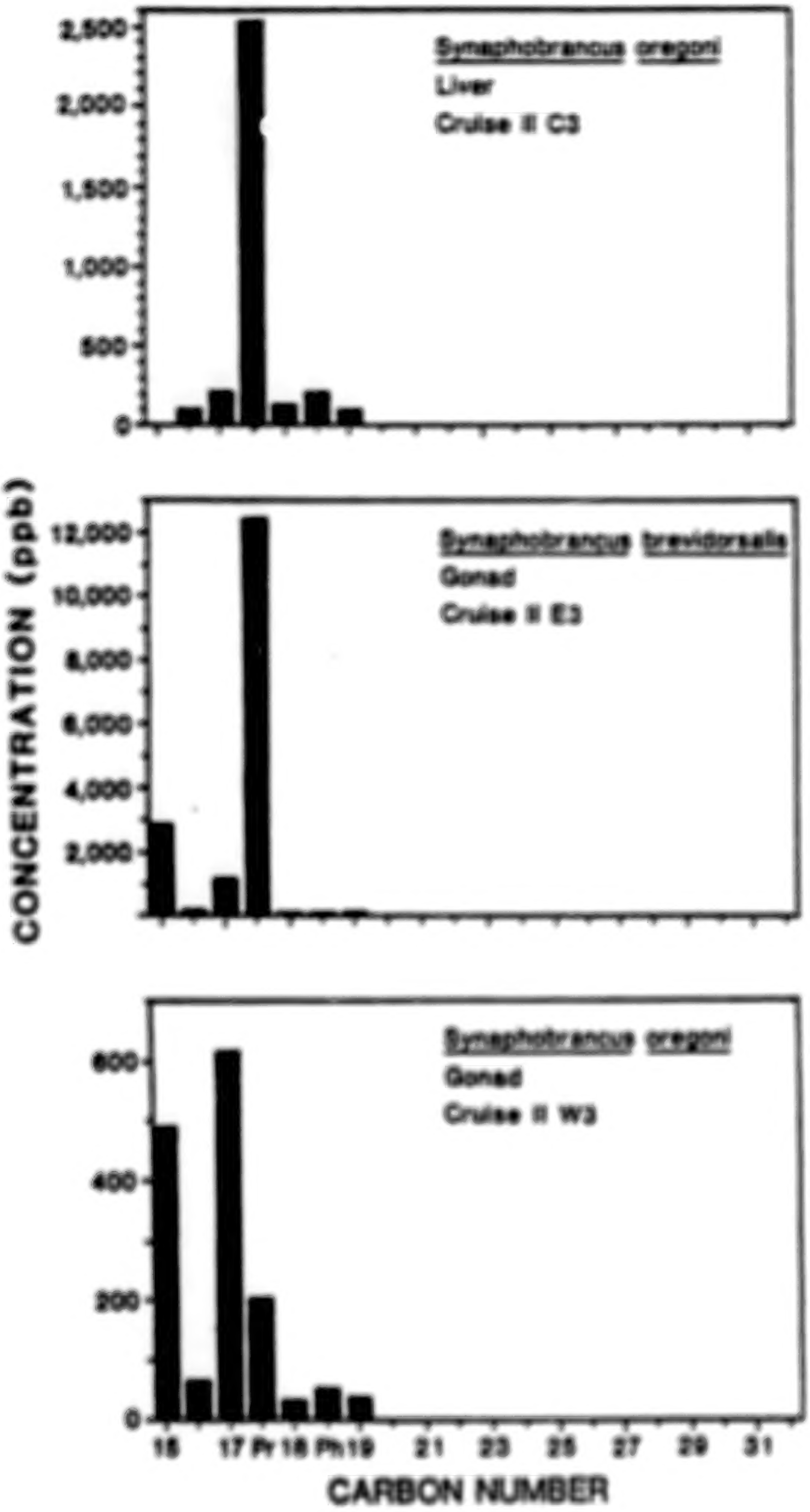

Figure 3-28. Selected examples of alkane distributions in eel tissues (Pr = pristane, Ph = phytane).

Table 3-9. Species in which a sediment hydrocarbon signature was detected in organism tissues.

Cruise	Station	Species	Organ	Type
III	C6	*Urophycis cirratus*	Gonad	Fish
III	C6	*Urophycis cirratus*	Liver	Fish
III	C10	*Geryon quinquedens*	Gonad	Crab
III	C8	*Geryon quinquedens*	Muscle	Crab
III	C10	*Geryon quinquedens*	Muscle	Crab
III	C7	*Geryon quinquedens*	Gonad	Crab
III	C1	*Steindachneria argentia*	Gonad	Fish
III	C8	*Coryphaenoides mexicanus*	Muscle	Fish
III	E3	*Nematocarcinus rotundus*	Muscle	Shrimp*
III	C7	*Heterocarpus oryx*	Gonad	Shrimp
III	C7	*Heterocarpus oryx*	Muscle	Shrimmp

*Petroleum signature.

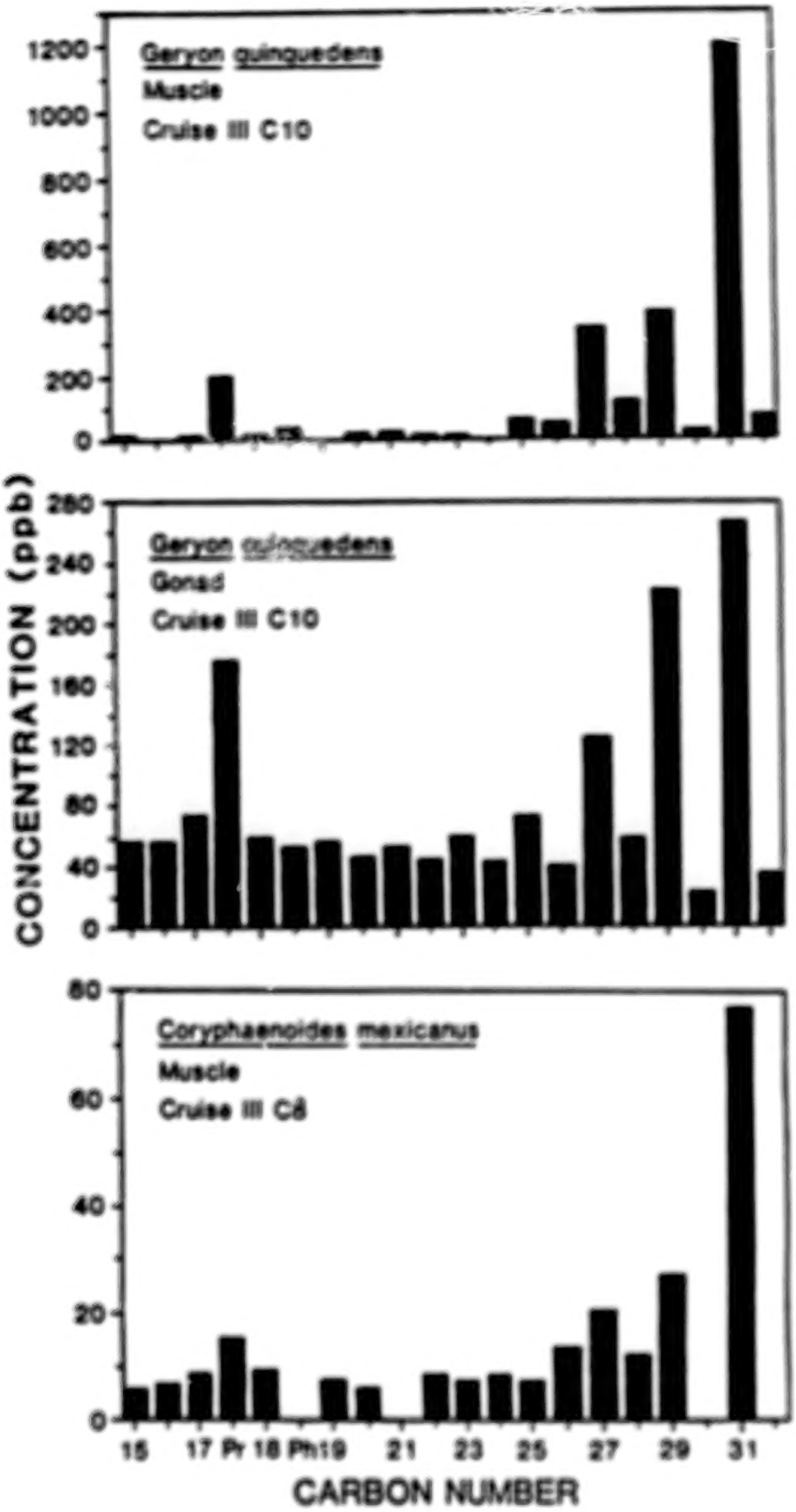

Figure 3-29. Selected examples of terrestrial hydrocarbons detected in crab and fish tissues (Pr = pristane, Ph = phytane).

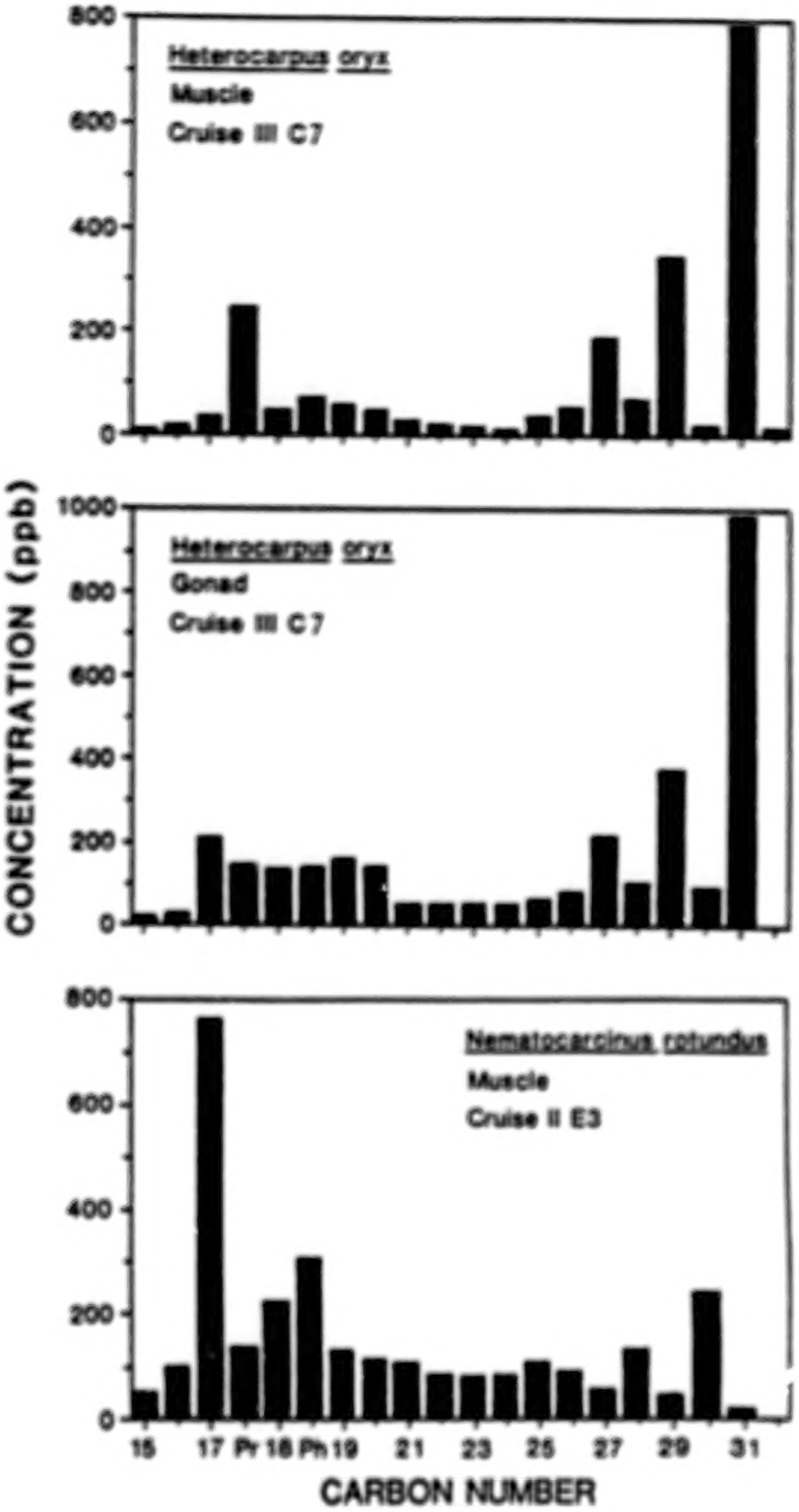

Figure 3-30. Selected examples of terrestrial hydrocarbons detected in shrimp and fish tissues (Pr = pristane, Ph = phytane).

the liver and/or gonads as well as the muscle tissue. The presence of the sediment hydrocarbons in tissues suggest that these organisms either ingested sediments and/or other organisms that had previously ingested sediments.

On average the highest alkane concentrations were detected in liver and gonad tissues, though there are high hydrocarbon levels present in some muscle tissues as well (Fig. 3-31). A suggested scheme of hydrocarbon sources and sinks on the Gulf of Mexico continental slope is shown in Figure 3-32.

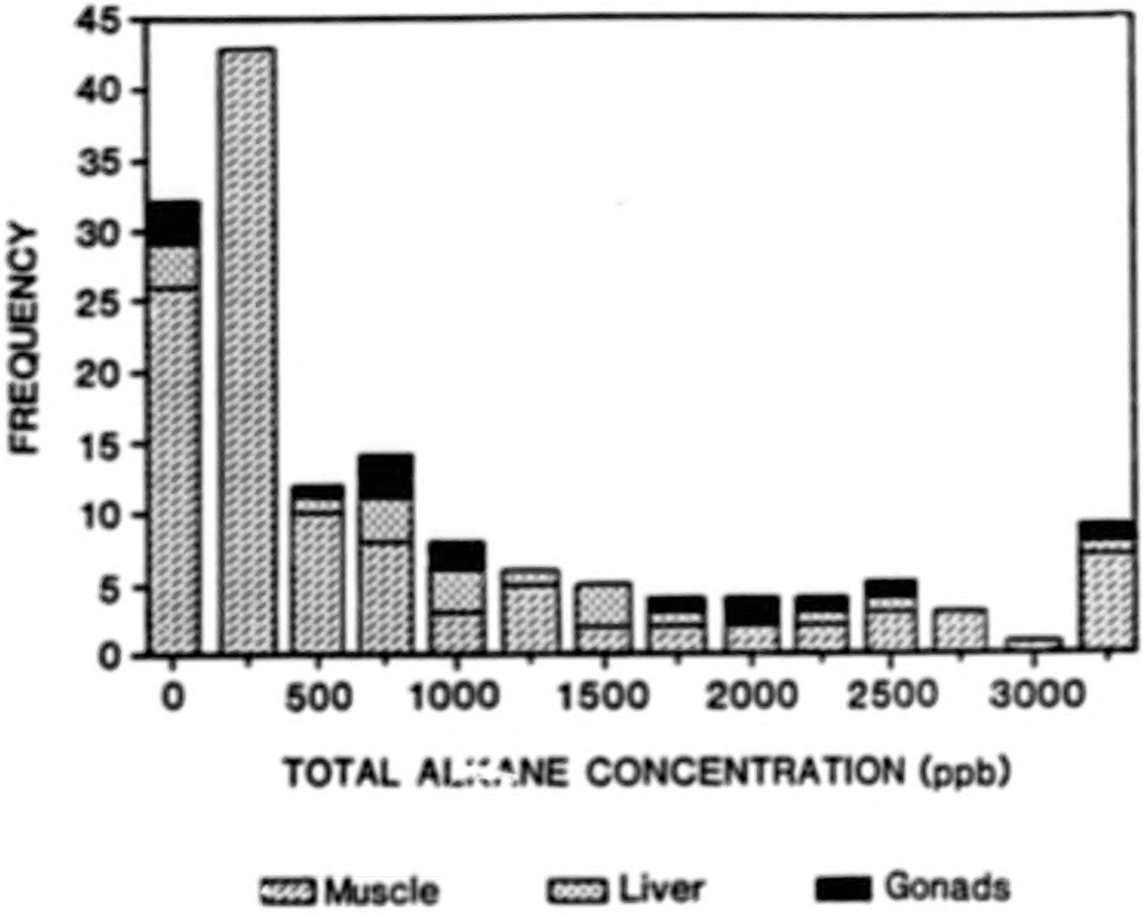

Figure 3-31. Summary of total alkane concentrations from Cruises I, II and III as a function of tissue type of all organisms analyzed.

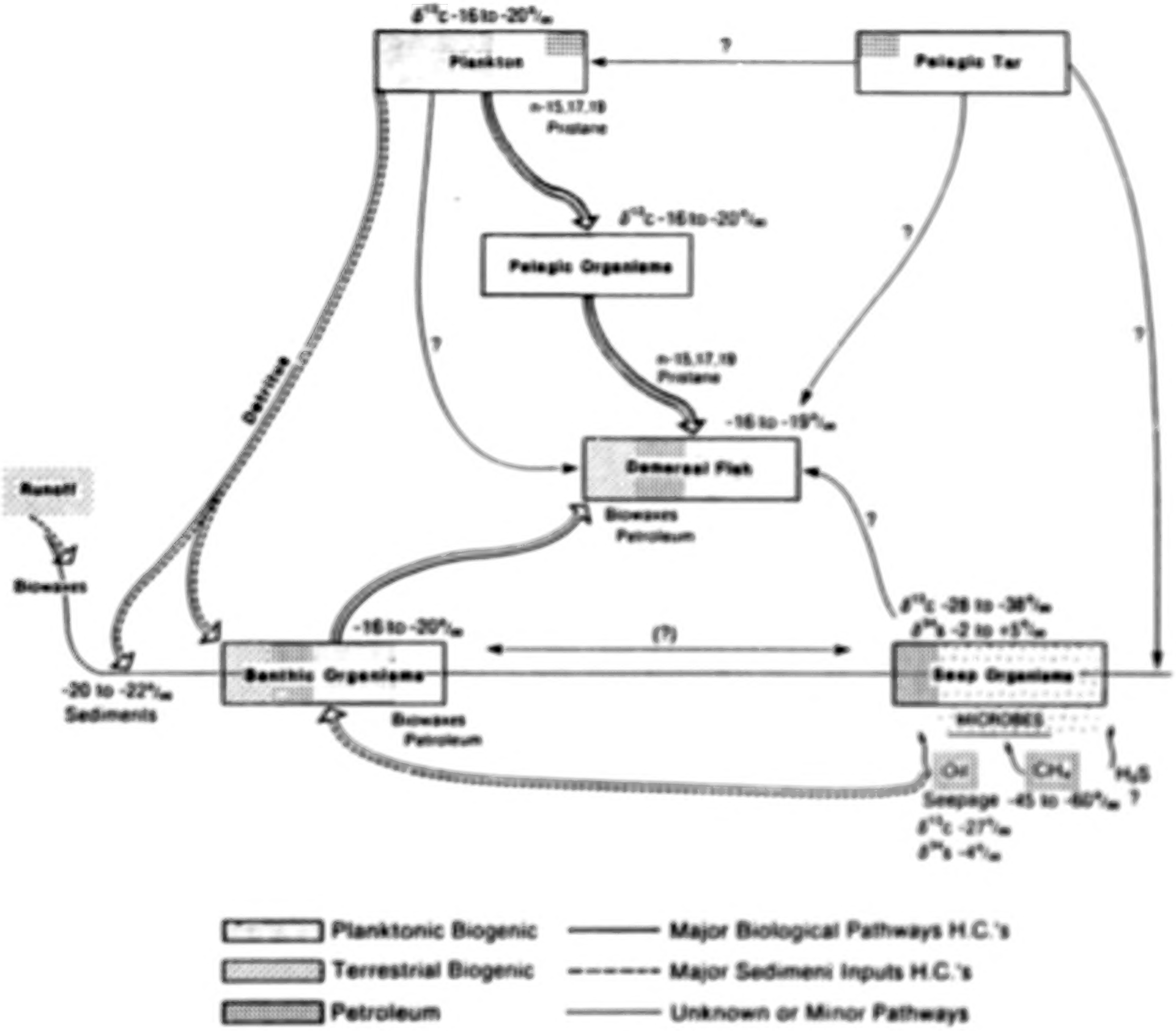

Figure 3-32. A suggested scheme for the sources and sinks of hydrocarbons on the Gulf of Mexico slope (note: the size of the various boxes do not represent quantitative importance).

4.0 BIOLOGICAL OCEANOGRAPHY OF THE NORTHERN GULF OF MEXICO CONTINENTAL SLOPE

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4.0 BIOLOGICAL OCEANOGRAPHY OF THE NORTHERN GULF OF MEXICO CONTINENTAL SLOPE

The faunal groups discussed in this study include the meiofauna (0.063-0.3 mm), collected by box corer, the macrofauna (greater than 0.3 mm in size) also collected by box corer, and the megafauna (both invertebrates and demersal fishes), which were collected by trawling. Of these groups, only the meiofauna and certain macrofaunal groups, such as Nematoda, Harpacticoida, Kinorhyncha, and a few others, were not identified to the species level.

The results of the five cruises discussed in this report suggest that it is now possible to predict with a reasonable degree of certainty the basic composition of the faunal communities on the northern Gulf slope between the 300 and 2500-m isobaths lying between 85° and 94° west longitude. Furthermore, it is also evident that there is a reasonable degree of agreement between the faunal findings discussed in a previous MMS study of the Gulf (Pequegnat 1983) and the present MMS study conducted by LGL. This is not to say that significant new discoveries have not been made, for they have. For instance, the discovery of the "seep communities" in the north-central Gulf goes well beyond the recognition of a unique kind of community in that it shows that matter and energy reductions can be a major factor limiting community developments in the deep sea. Also, new species of organisms have been uncovered during every cruise. The numbers of new species in such macrofaunal groups as the Tanaidacea, Cumacea, and Ectoprocta, to mention but a few, were not anticipated. Very likely the same would be true of the meiofauna were we to study it intensively. More surprising, perhaps, is the fact that a rather large number of new species and first records for species were revealed by a careful study of the megafaunal decapods alone. For instance, two new species of galatheids (in the genera *Munidopsis* and *Phylladiorhynchus*) are being described (L.H. and W.E. Pequegnat), two new species of brachyuran crabs in the genus *Cymonomus* are being described by D. Felder, a new pagurid in the genus *Parapagurus* is being described by R. Lemaitre, and two new species of carideans, viz., *Bythocaris* sp. A, and *Palaemonella* sp. A are being described by R. Heard.

The number of species of decapods found for the first time in the Gulf or that are considered extremely rare by specialists is too large to detail here, but the tally is an impressive one. A complete list of the species identified from Cruises I-V from all sampling efforts can be found in Volume III of this report series.

4.1 MEIOFAUNA

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4.1 MEIOFAUNA

4.1.1 COLLECTION RESULTS

Meiofauna samples were taken from the 2 cm (i.d.) coring tubes afixed to the sides of the box cores. (See Section 2.3.1.2 for a description of box core methods and materials.) The usual sample design was to collect duplicate tubes (for a total of 19.4 cm²) from each of six replicate box cores at each station. The counts in these tubes were combined and considered one replicate sample per box core. Of the planned 60 sampling stations, 59 were successfully completed. During Cruise II, three or four replicates were collected at the Eastern and Western Transect stations; six replicates were collected on all of the remaining cruises. Appendix Table C1-1 shows the sampling design for the entire meiofauna collection obtained during the program.

Meiofauna were defined as metazoan organisms retained on a 63 um screen; counts of protozoan Foraminifera, though noted, have not been included in this discussion. This is consistent with the definition provided by Theil (1983). A total of 43 major groups were identified; of these, representatives of five taxa of permanent meiofauna (Nematoda, Harpacticoidea, Polychaeta, Ostracoda, and Kinorhyncha) along with naupliar larvae (temporary meiofauna) comprised 98% of the collections. Table 4-1 shows the total occurrence of the dominant groups in the entire collection. (A detailed tabulation of densities at individual stations can be found in Appendix Tables C1-2 through C1-6) The abundances in Table 4-1 have also been presented as densities per 10 cm² according to the total area of the replicates (Theil 1983); and as approximations of relative wet weight following published estimates of group weights (Rowe, et al. 1974, Fauble 1982). The nematodes, harpactacoids, and nauplii were numerically dominant throughout the collection and in the mean densities per replicate; however, because of their much greater size, the less abundant polychaetes and ostracods probably contributed significant biomass.

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Table 4-1. Overall abundance and estimated biomass of the meiofaunal collection.

Taxa	Overall Abundance	Mean Density per 10 sq. cm	Standard Error	Wet Weight Multiplier	Approximate Wet Weight µg
Nematoda	135,167	414.62	10.25	0.85	114,892
Harpactacoida	41,826	128.3	3.11	2.8	117,113
Nauplii	30,119	92.39	2.75	2.15	64,756
Polychaeta	9,648	29.6	1.56	55.25	533,052
Ostracoda	6,118	18.77	0.58	39.15	239,520
Kinorhynch	2,222	6.82	0.41	2.8	6,222
All other taxa	5,648	0.91	0.13	NA	75,730
Total	230,748	707.82	16.2		1,151,283

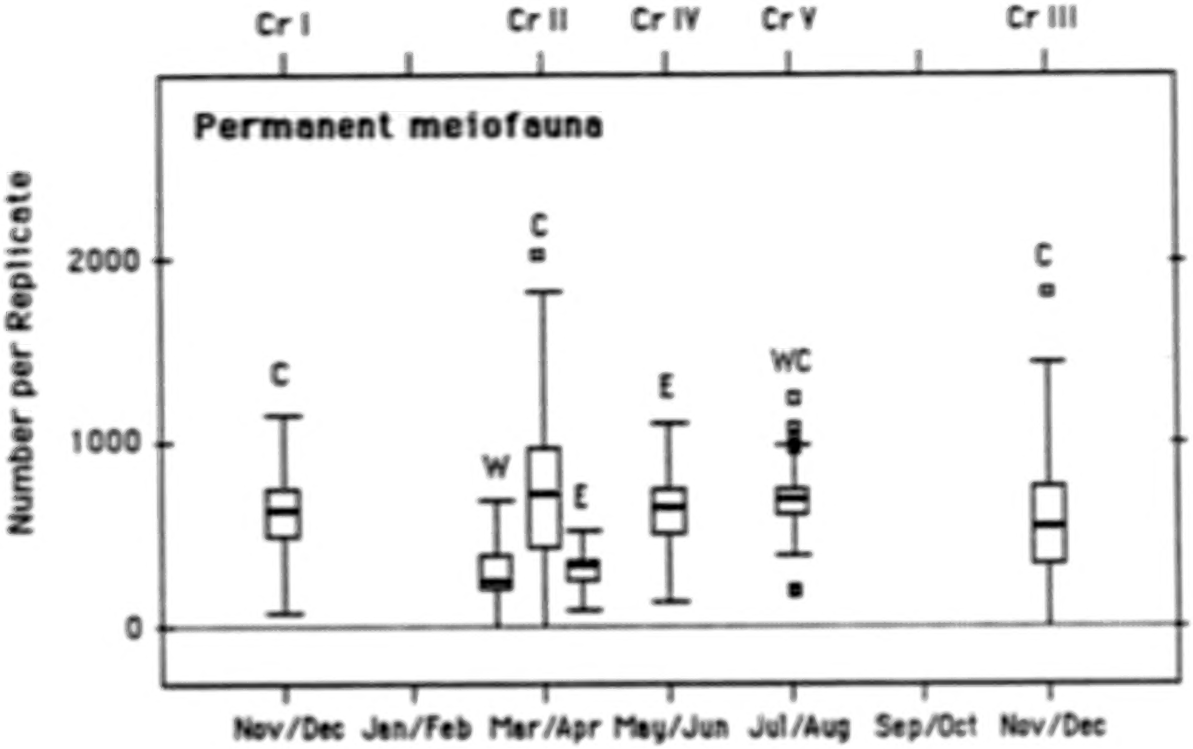
4.1.2 SEASONAL COMPARISONS

The occurrence of all permanent meiofauna groups and of naupliar meiofauna was compared among transects and cruises by plotting the median and quartile values for the density of specimens per replicate (Fig. 4-1). The plots were arranged to show seasonal differences between samplings. The median densities of the permanent meiofauna were similar for all of the transects with the exception of the Eastern and Western Transect samples collected during Cruise II; no seasonal differences were apparent. The density of nauplii collected during the spring and summer cruises was generally higher than the densities observed in th two fall collections, although the Cruise II Western and Eastern Transect collections were depressed for this group as well.

Seasonality in abundance of both permanent and temporary meiofauna has been reported for coastal and estuarine collections (Rudnick et al. 1985); however, deep sea collections have generally not shown clear seasonal patterns (Theil 1983). The apparent seasonal differences in nauplii densities may also have resulted from differences in the depth ranges of the transects and individual variability between stations. Rigorous comparison of seasonal differences would require a level of replication that was not obtained in this study. In the absence of gross differences, the meiofauna data presented below were treated as though season fluctuations did not exist.

4.1.3 COMPARISON OF MEIOFAUNA WITH MACROFAUNA BY DEPTH

The occurrence of all meiofaunal groups was compared with the total macrofauna collection at the 59 sampling stations. The upper panel of Figure 4-2 shows regressions of the log of the numbers of meiofauna and macrofauna per square meter plotted against depth (see Theil 1983, pg. 215 for similar treatment). Both regressions were significantly different from zero ($p = 0.01$). The density of meiofauna was approximately two orders of magnitude greater than the density of macrofauna throughout the depth range of the sampling stations. The range in density of meiofauna among the sampling stations was approximately one order of magnitude; the range of macrofaunal densities was somewhat narrower. Densities of both



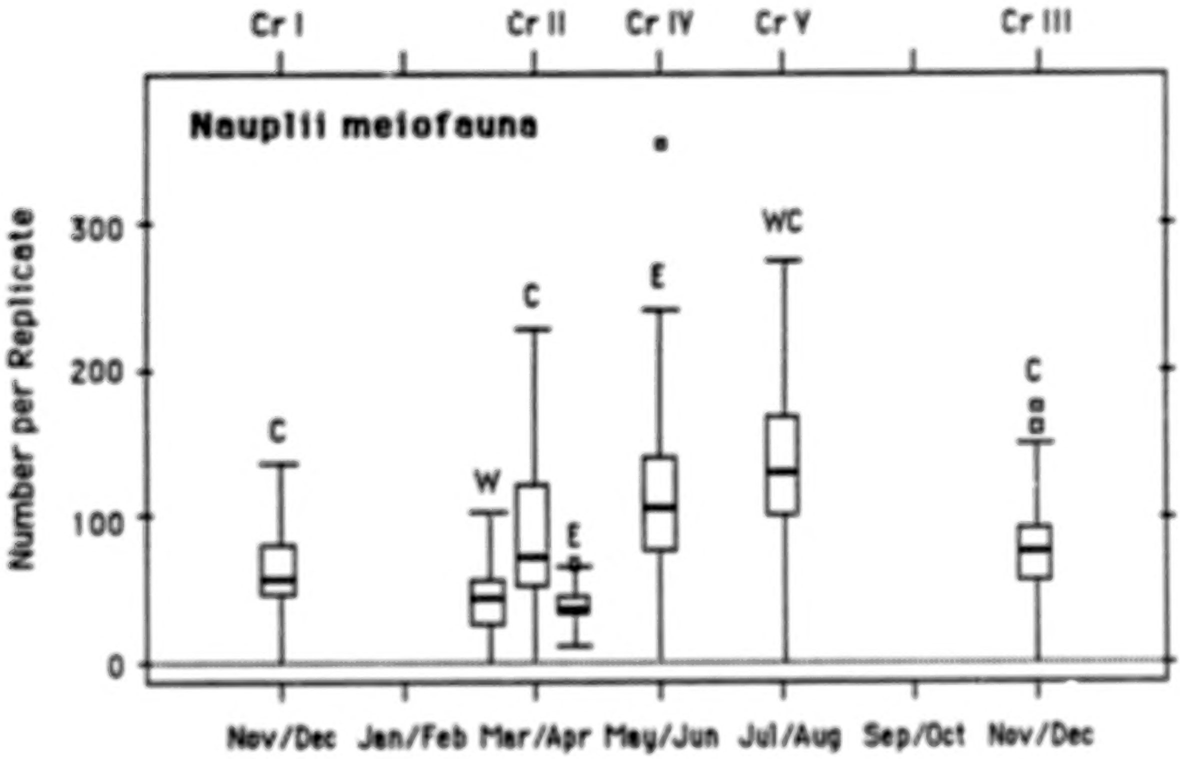


Figure 4-1. Comparison of median numbers of permanent and nauplii meiofauna arranged by season collected. The boxes show the range of the 25th to 75th percentiles; the median is indicated by the heavy line. Whiskers are 1.5 times the range of the boxes.

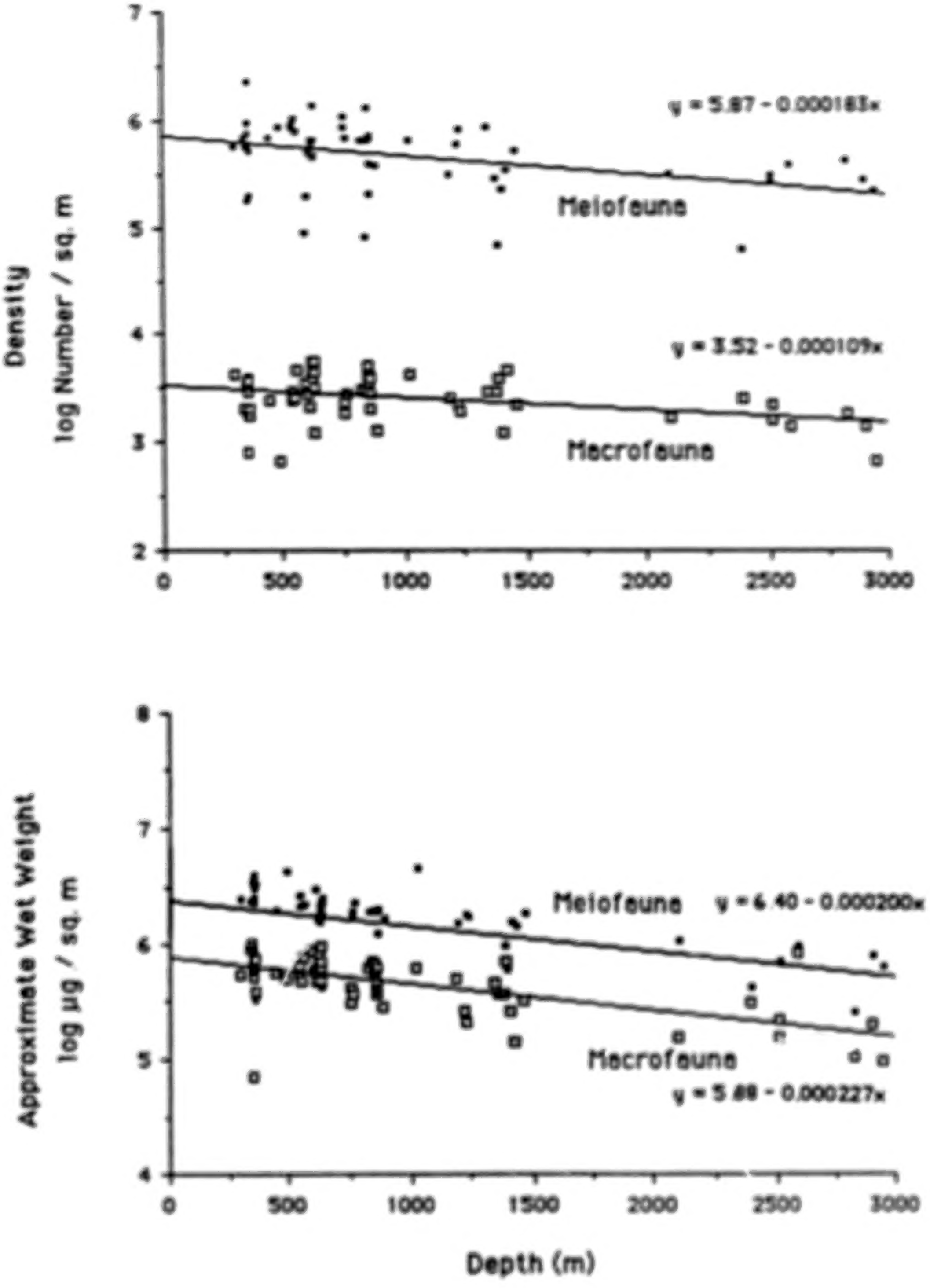


Figure 4-2. Relative occurrence of meiofauna and macrofauna with depth at all sampling stations. Upper plot shows log of density per square meter. Lower plot shows log of approximate biomass per square meter.

meiofauna and macrofauna decreased with increasing depth. The rate of decrease was slightly less for the macrofauna than for the meiofauna; however, analysis of covariance would be required to test the difference between the two slopes. The regression plots in Figure 4-2 suggest that there was a threefold decrease in the density of meiofauna and a twofold decrease in the density of macrofauna between 300 and 3000 m depths.

The lower panel of Figure 4-2 shows regressions of the log of approximate wet weight for meiofauna and macrofauna. Approximate wet weights per m^2 were calculated by multiplying the densities of each of 43 meiofaunal and 44 macrofaunal groups, respectively, by appropriate estimates of wet weight per individual (Rowe et al. 1974, Fauble 1982). As with density, the approximate wet weight of both groups decreased with increasing depth. In this case, however, the rate of decrease for macrofauna was slightly greater than for meiofauna. The regression plots in Figure 4-2 suggest that there was a three-and-one-half-fold decrease in the biomass of meiofauna and a fourfold decrease in the biomass of macrofauna between 300 and 3000 m depths.

4.1.4 CHANGES IN DENSITY WITH DEPTH

The variation in density of all meiofaunal groups among replicated samples was compared in plots of mean density (individuals/10 cm^2) for the sampling transects in the western, central, and eastern sections of the study area (Figs. 4-3 through 4-6). The comparison showed that there were some significant differences ($p = 0.05$) among stations within transects. In general, the shallowest stations had significantly higher densities than the deepest stations; however, no clear pattern of significant change was evident.

On Cruise I, stations on the Central Transect those deeper than 1000 m in depth had significantly lower meiofauna densities than those shallower than 1000 m depth (Fig. 4-3). This pattern was not repeated among the Cruise II Central Transect stations but a decrease was suggested. Densities observed on the Central Transect during Cruise III showed a high level of variability and stations at 492, 1021, 1465, and

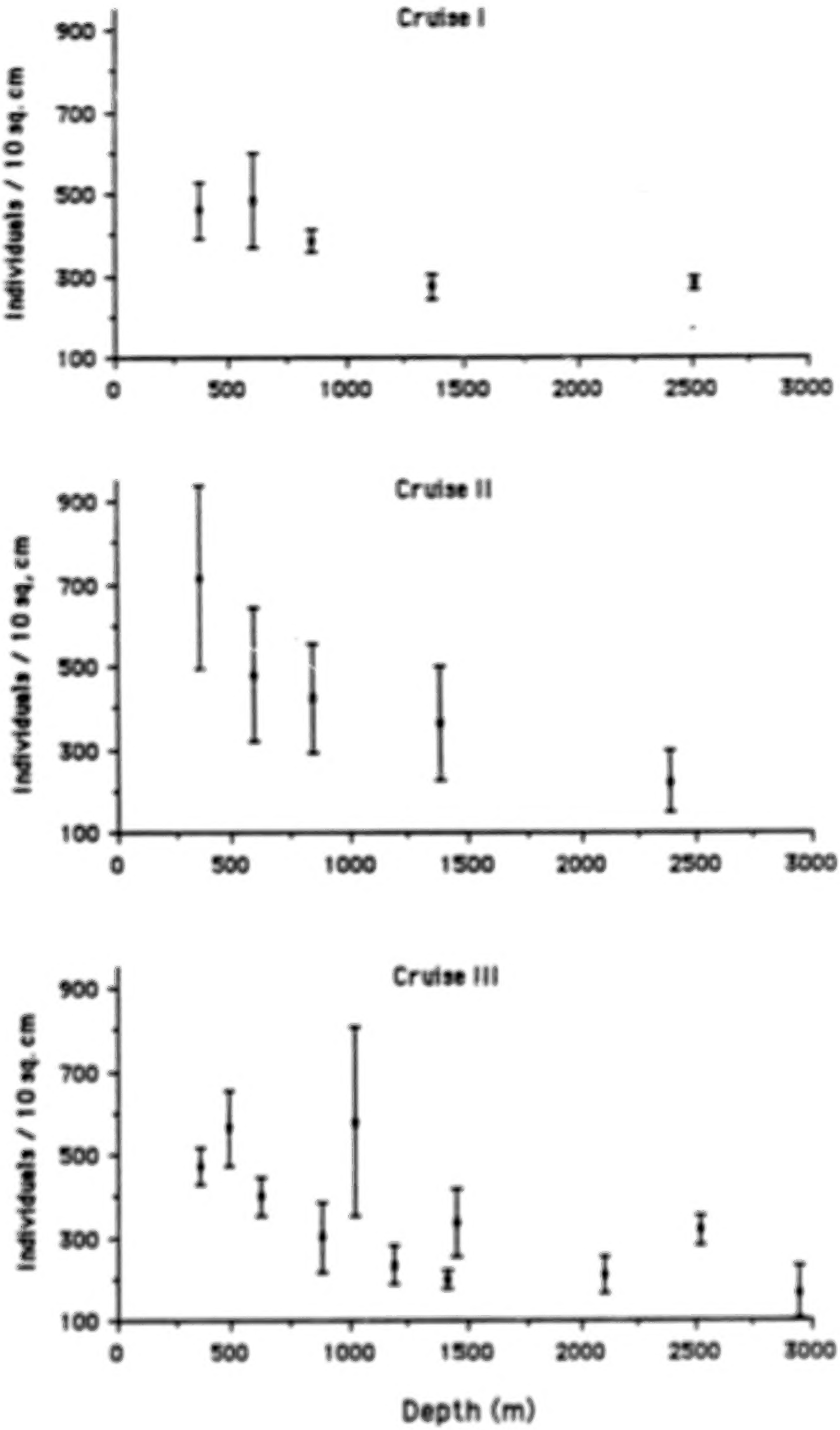


Figure 4-3. Mean densities of all meiofaunal groups collected at Central Transect stations. Bars show ±2 standard errors of the means.

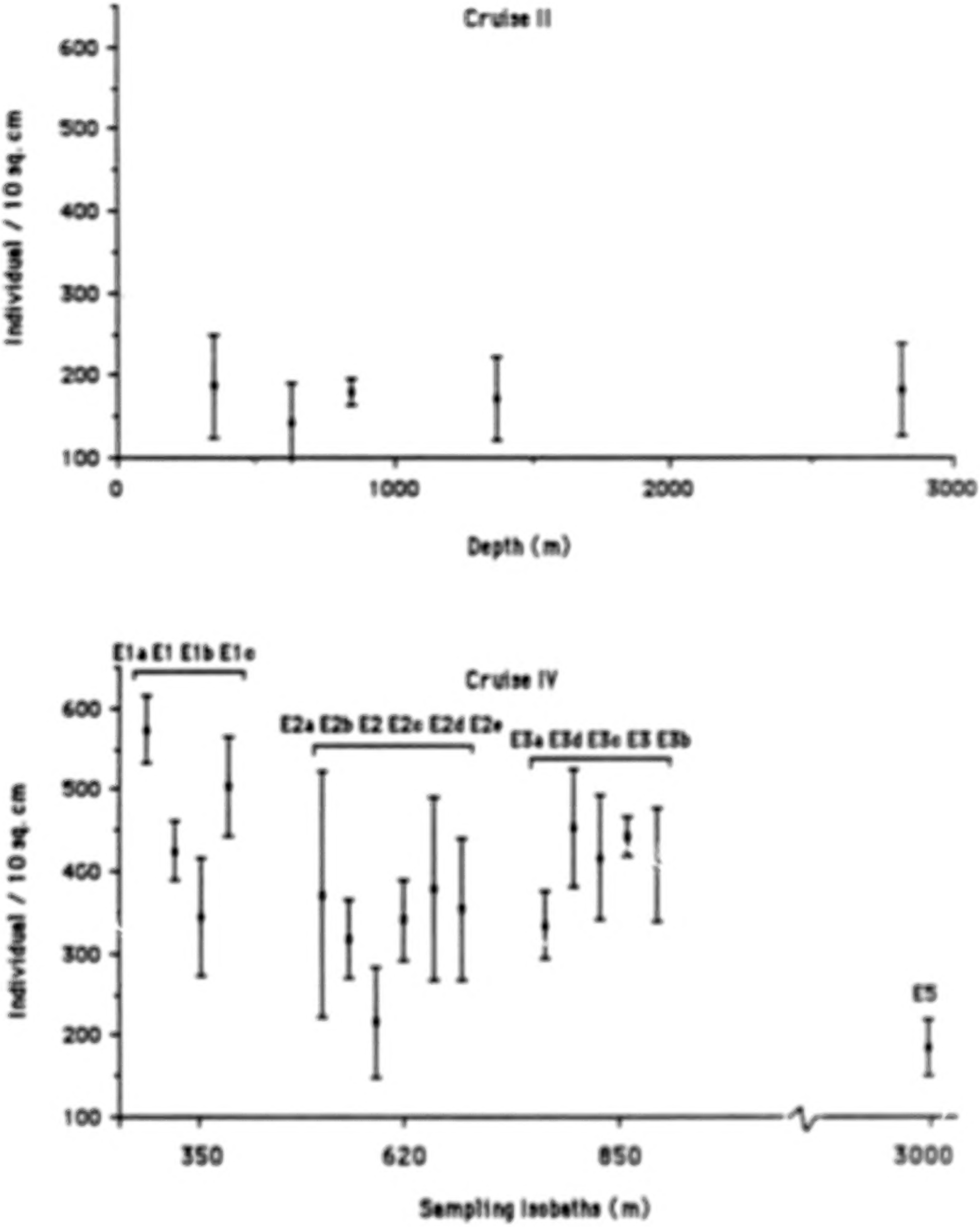


Figure 4-4. Mean densities of all meiofaunal groups collected at Eastern Transect stations. Bars show ± standard errors of the means. The Cruise IV stations are arranged by sampling isobath to show differences between stations at the same approximate depths.

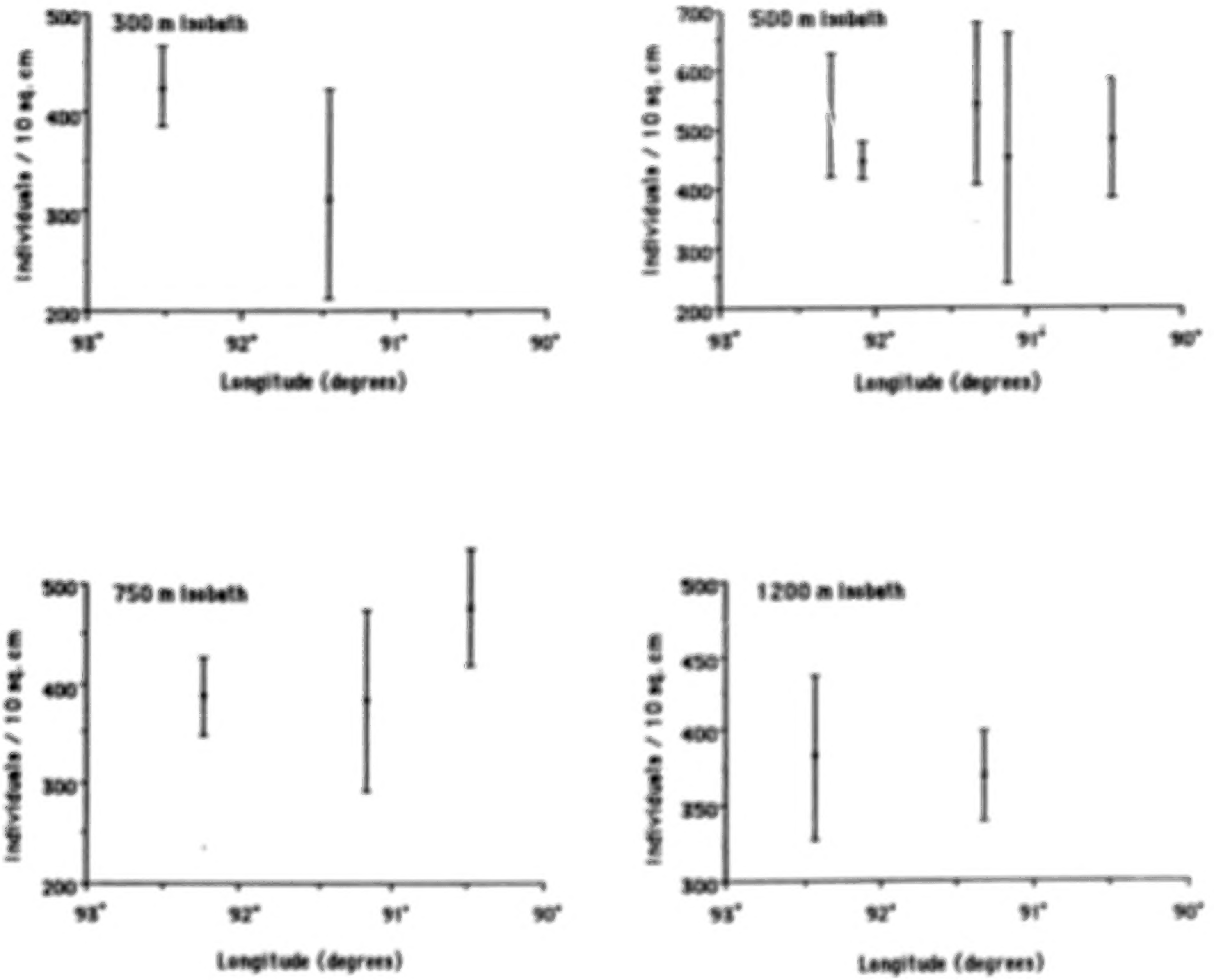


Figure 4-5. Mean densities of all meiofaunal groups collected at Western-Central Transect stations. Bars show ±2 standard errors of the means. Stations are arranged by sampling isobath to show differences between stations at the same approximate depths.

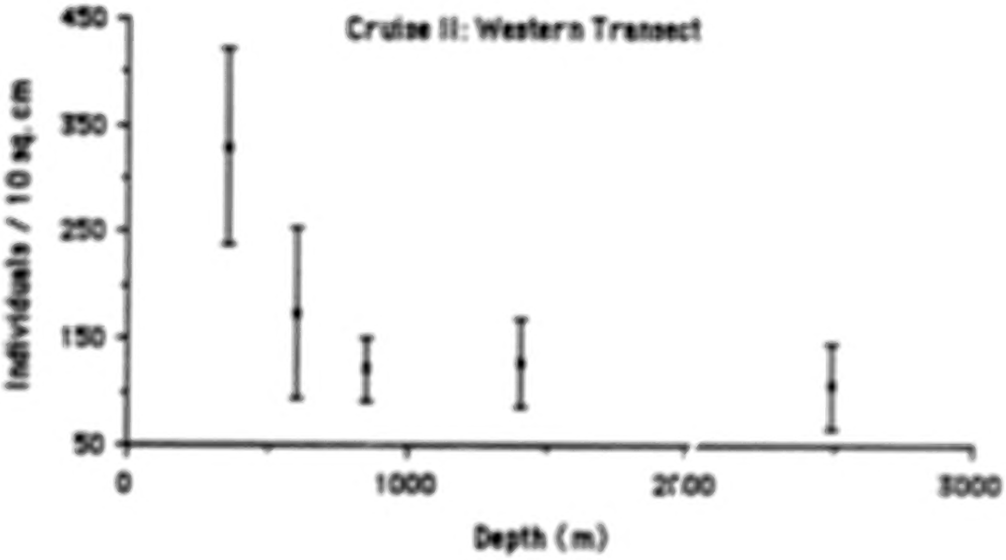


Figure 4-6. Mean densities of all meiofaunal groups collected at Cruise II, Western Transect stations. Bars show ±2 standard errors of the means.

2518 m depth (Stations C6, C7, C4, and C5, respectively) were anomalous with the trend of decreasing density with increasing depth.

There were no significant differences in meiofaunal densities among the Cruise II Eastern Transect stations (Fig. 4-4). Sampling the 350, 620, 850, and 3000 m isobaths during Cruise IV indicated, with one exception, that the three shallower depths had significantly greater meiofaunal densities than the 3000 m station. Although there were some significant differences within the isobaths as well as between the isobaths. Densities observed during Cruise II were generally markedly lower than during Cruise IV.

The sample collection from the Western-Central Transect during Cruise V (Fig. 4-5) compared densities within depth isobaths over distances of approximately 50 to 100 nm. Although mean densities varied along this transect, they were not significantly different within isobaths, nor were there apparent trends in the means.

Meiofaunal densities in the Cruise II Western Transect stations were similar to the Cruise II Central Transect stations (Fig. 4-6). The densities observed at the deepest station were significantly different from the shallowest station. There were no significant differences between the stations at intermediate depths.

4.1.5 VARIATION IN COMPOSITION WITH DEPTH

Mean densities of the six most abundant meiofauna groups at individual stations were plotted for Cruises I-V (these will be shown in Figs. 4-7 through 4-11). Numerical dominance of the nematodes and harpacticoids was apparent throughout the collections; however, accompanying plots of approximate wet weight were provided as an indication of differences in biomass. As expected, the polychaetes and ostracods were the dominants with respect to weight. The densities of the six dominant meiofauna groups declined overall with increasing depth. The trend was not distinct, however, nor were there consistent patterns in the changes in density for the individual groups. Patterns apparent in changes in density were often reversed when the occurrence of meiofauna was expressed as approximate wet weight.

4.1.5.1 Cruise I

On Cruise I, the density of nematodes declined only slightly with depth with even a slight increase in density going from Station C4 to Station C5, the deepest station (Fig. 4-7). Changes in density were most apparent as a decline in the abundance of harpacticoids and nauplii. Abundance of polychaetes, ostracods, and kinorhyncs decreased as well, although this decrease was poorly resolved when plotted as density. The approximations of wet weight, however, showed a much sharper decline with depth. Decrease in the larger but less numerous polychaetes and ostracods was readily apparent when expressed as weight, while the contribution of the nematodes was more or less constant.

4.1.5.2 Cruise II

Differences in meiofaunal composition between the Western, Central, and Eastern Transects were clearly shown in the plots for the Cruise II stations (Fig. 4-8). Sampling effort was not equal among the transects; three replicates were collected at Western Transect stations, six at Central Transect stations, and three or four replicates at the Eastern Transect stations. However, the differences in effort do not explain the substantial differences between mean densities at stations of similar depths shown in Figure 4-8. The Central Transect station densities were consistently greater than the Western Transect stations of similar depths by a factor of two or greater. The density of nematodes was particularly noteworthy at Station C1, which also provided the highest overall densities of meiofauna seen during the five cruises.

Decline in both density and approximate wet weight occurred with increasing depth in the Central Transect stations. This decline with depth was less apparent in the Western Transect stations and did not occur in the Eastern Transect stations. The occurrence of meiofauna decreased sharply between Stations W1 and W2, both in terms of density and biomass; however, the subsequent stations showed little decrease with depth. On the Eastern Transect stations, the overall density remained generally constant with increasing depth except for a slight decrease in the density of nematodes that registered at Station E4. When expressed as approximate

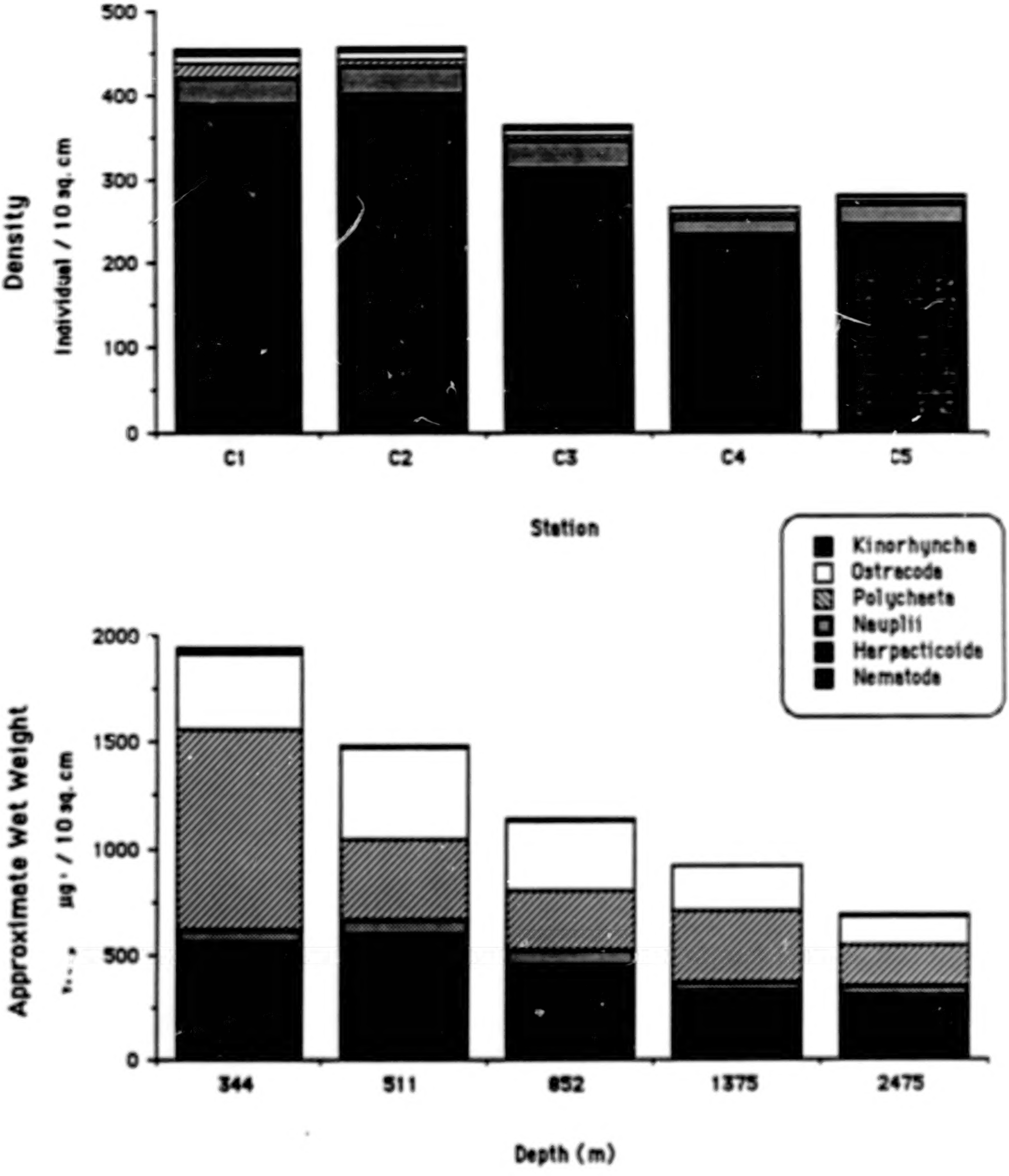


Figure 4-7. Densities and approximate wet weights for the six most abundant meiofaunal groups collected during Cruise I, Central Transect.

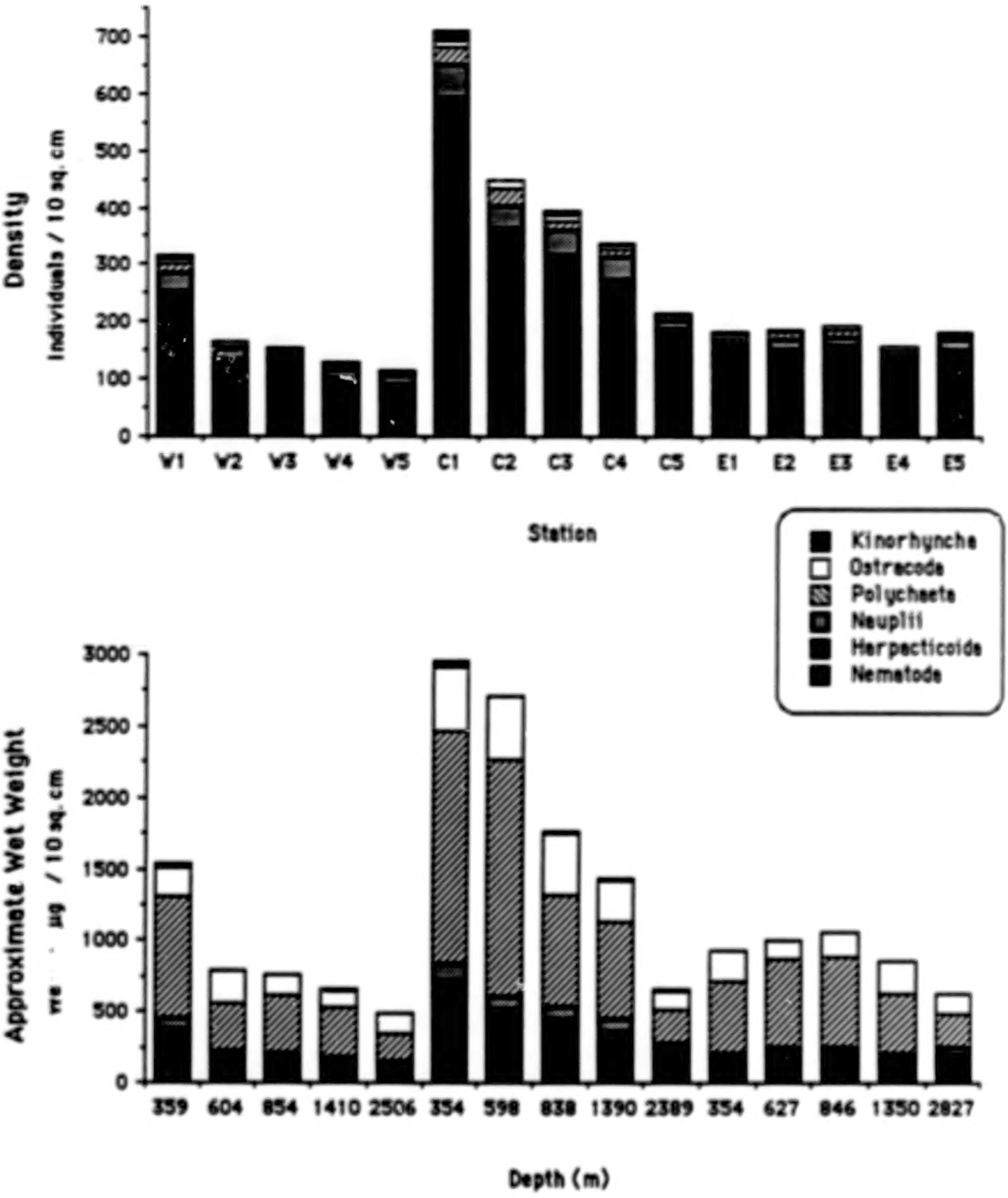


Figure 4-8. Densities and approximate wet weights for the six most abundant meiofaunal groups collected during Cruise II, Western, Central, and Eastern Transects.

wet weight, the occurrence of meiofauna on the Eastern Transect stations actually increased with depth between Stations E1 and E3 (354 to 846 m depth). This increase was due to increased abundance of polychaetes at Stations E2 and E3.

4.1.5.3 Cruise III

Occurrence of meiofauna on Cruise III (Central Transect) stations was variable across the depth gradient sampled (Fig. 4-9). Densities of meiofauna decreased, in general, between the shallow and deep stations; however, noteworthy exceptions to this trend occurred at Stations C7, C4, and C5. The reversals were primarily due to increased abundance of nematodes, although the abundances of the other major groups were also elevated in comparison with adjacent stations. When density was expressed in terms of approximate wet weight the predominance of polychaetes at Station C7 became evident.

Comparison of meiofauna occurrence at Cruise III stations with the Central Transect collections made during Cruises I and II (Figs. 4-7 through 4-9) showed the relative composition of the six major groups to have been mostly constant between samplings. Nematodes and harpacticoids were the most abundant groups at all stations. Nauplii were more abundant than polychaetes except at Station C7 on Cruise III. Ostracods and kinorhynch were the least abundant groups at all stations. There was also good agreement among the stations that were sampled on each of the three Central Transect cruises (C1-C5), although elevated abundance, particularly of nematodes, was observed during the Cruise II sampling.

4.1.5.4 Cruise IV

The Cruise IV sampling returned to Stations E1, E2, E3, and E5 that were sampled during Cruise II. In addition, more stations in the same respective isobaths as E1, E2, and E3 were also sampled. Figure 4-10 shows the isobathic stations arranged northwest to southeast. Occurrence of the nematodes across this station array was variable; however, there was no trend of abundance either with increasing depth or with longitude within the three sets of shallower stations. Station E5 (2901 m depth)

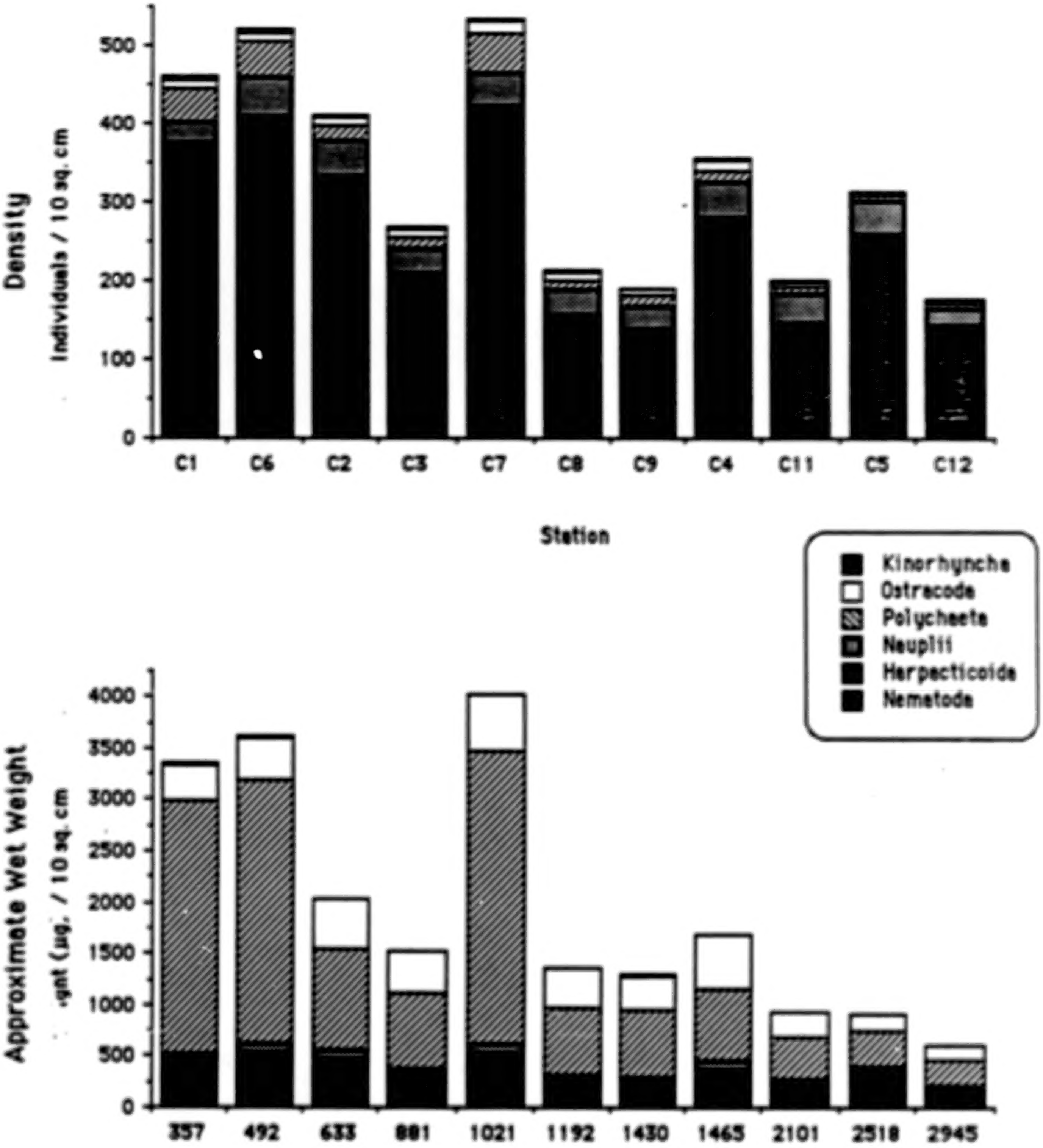


Figure 4-9. Densities and approximate wet weights for the six most abundant meiofaunal groups collected during Cruise III, Central Transect.

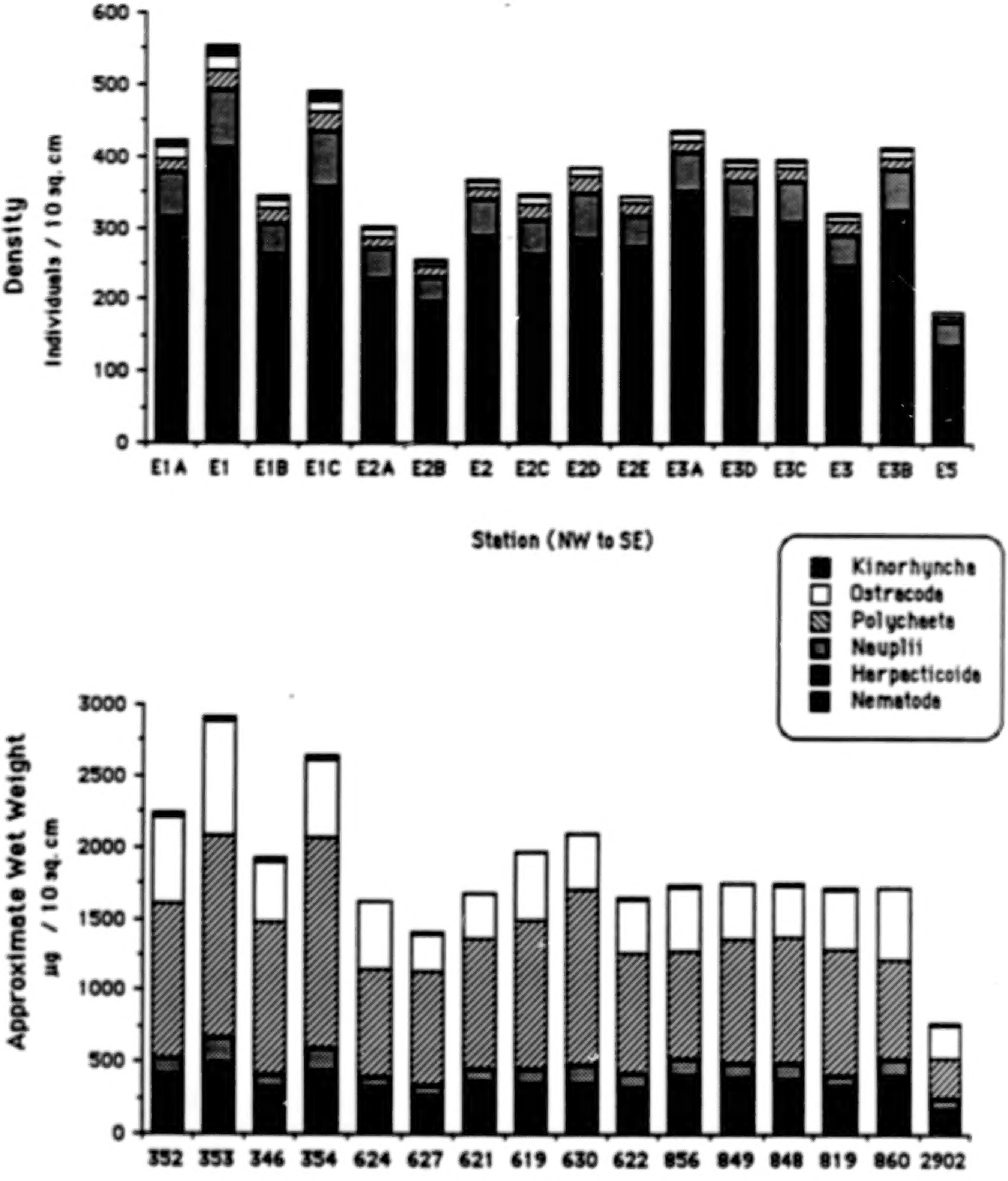


Figure 4-10. Densities and approximate wet weights for the six most abundant meiofaunal groups collected during Cruise IV, Eastern Transect.

had the lowest abundance of nematodes and all other groups. The abundance of nematodes was generally lower in the 620 m isobath stations (E2A-E2E) than it was in the 350 m and 850 m isobath stations (E1A-E1C and E3A-E3D). In contrast with the Central Transect samplings, harpacticoids were generally less abundant than nauplii in the Cruise IV collection. The plots of approximate wet weight showed a greater representation by ostracods than was seen in the Central Transect stations. Stations E1 and E1C had the greatest abundance of ostracods seen during the project.

Abundance of meiofauna was substantially greater for the shallow- and intermediate-depth stations (350 to 850 m) sampled during Cruise IV than for the samples taken during Cruise II. The deepest station, E5, had similar abundances during both cruises. The differences in abundances between Cruises IV and II were reflected in all six major groups to a similar degree.

4.1.5.5 Cruise V

The station array in Cruise V allows comparison of meiofauna abundance along isobaths between the Western and Central Transects (Fig. 4-11). No distinct trends in abundance were evident, either with changes in depth or longitude, nor were any of the collections from individual stations anomalously dense or depauperate. The occurrence of nauplii and ostracods was greater in the Western-Central Transect than in either the Western or Central Transects. Overall occurrence of meiofauna was less than the Central Transect collections, but substantially greater than the West Transect collection.

4.1.6 DISCUSSION OF COMMUNITY ASPECTS

The decrease in occurrence of meiofauna with increasing depth has been reported in the Gulf of Mexico by Rowe (1971, 1974) and elsewhere by Theil (1983). The intercept and the slope of the regression of meiofaunal densities (see Fig. 4-2) agreed remarkably well with the decrease of meiofauna from different eastern Atlantic regions reported by Theil (1983; pg. 215). (Note that his description includes reports of densities from stations at 4000 m and 5000 m depths in addition to the slope depths.)

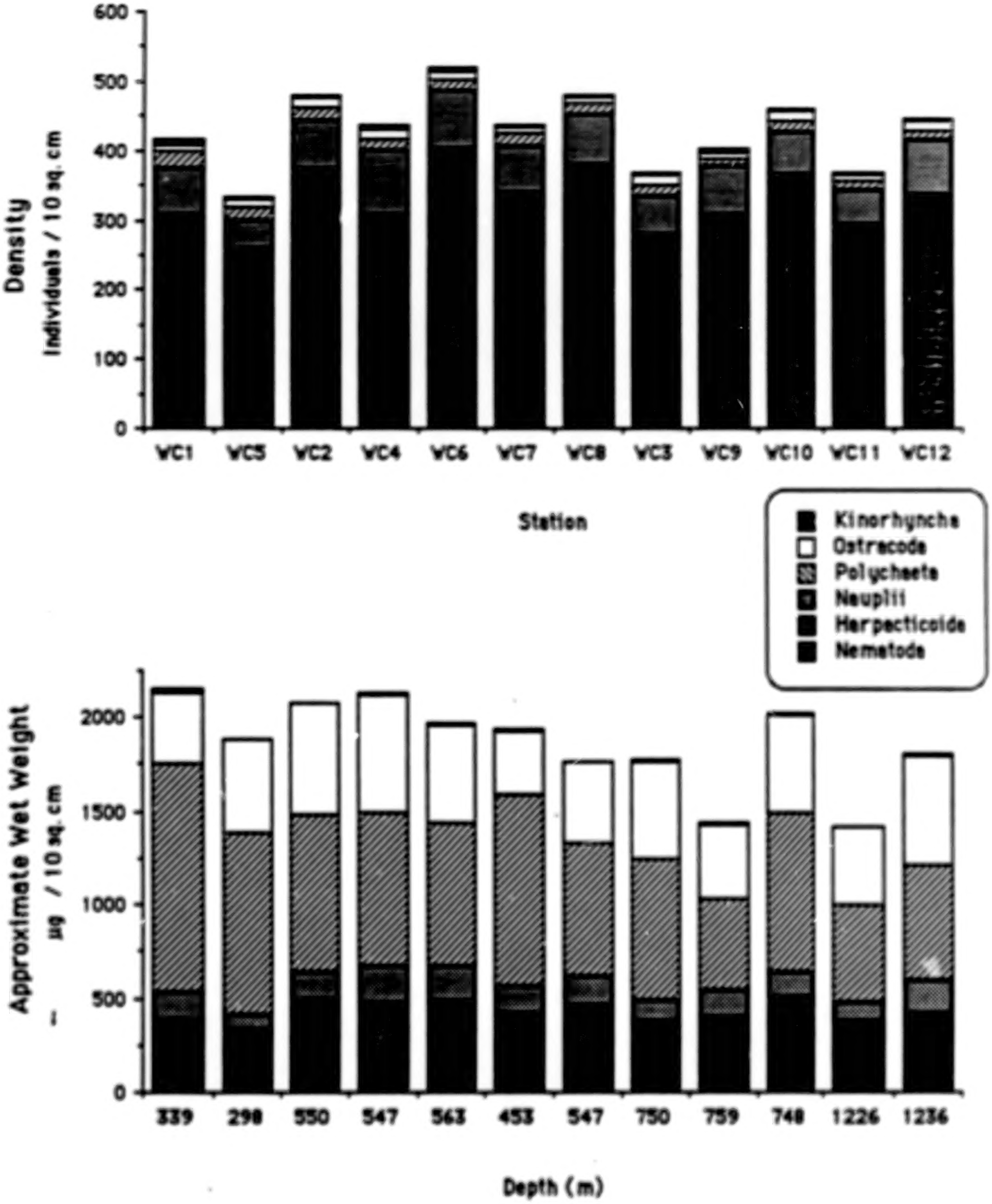


Figure 4-11. Densities and approximate wet weights for the six most abundant meiofaunal groups collected during Cruise V, Western-Central Transect.

Theil also compares occurrence of macrofauna in the northern Gulf of Mexico (data were obtained from Rowe and Menzel 1971) with the Eastern Atlantic meiofauna densities. He reports that the ratio of meiofauna to macrofauna increases with depth. One explanation for this change would be an overall decrease in the size of infaunal organisms with depth.

This hypothesis was not supported by the current findings. As Figure 4-2 shows, the ratio of numbers of meiofauna to numbers of macrofauna on the northern Gulf slope actually decreases with increasing depth. Approximations of biomass (Fig. 4-2) also showed a relative increase in macrofauna, although it was less pronounced than for density. This may indicate that the macrofauna as a group decreased in size with depth.

Trends in relative abundance of meiofauna and macrofauna, and in overall infaunal biomass may have been influenced by the representation of individual taxonomic groups. A cursory look at four groups consistently found in both the meiofauna and macrofauna (Nematoda, Harpacticoida, Polychaeta, and Ostracoda) indicated that the relative numbers of meiofaunal and macrofaunal representatives for each group undergo consistent changes with depth (Fig. 4-12). These patterns were distinct for each group. For example, the number of macrofaunal nematodes increases or remains constant with depth, while meiofaunal nematodes decrease with depth. Among the Harpacticoida, the densities of meiofauna generally decreased with depth, while the macrofauna showed the greatest densities at intermediate depths. Meiofaunal and macrofaunal polychaetes showed similar changes with depth, while macrofaunal ostracods showed an initial increase in density with depth. Because densities of nematodes were high, an increase in macrofaunal nematodes would increase the biomass of macrofauna relative to the biomass of meiofauna. A detailed study of these data might yield additional information concerning the relative occurrence of meiofauna and macrofauna.

Variability among replicate samples at a station and between stations at similar depths is clear from the plots shown in Figures 4-3 through 4-6. These data suggest that the density of meiofauna was not simply a function of depth. Consider the collections from the Central Transect (Fig. 4-3). This transect was sampled three times during two seasons; the trend of decreasing density with depth was apparent in all samplings. However, differences between Cruise II densities and those seen in Cruises

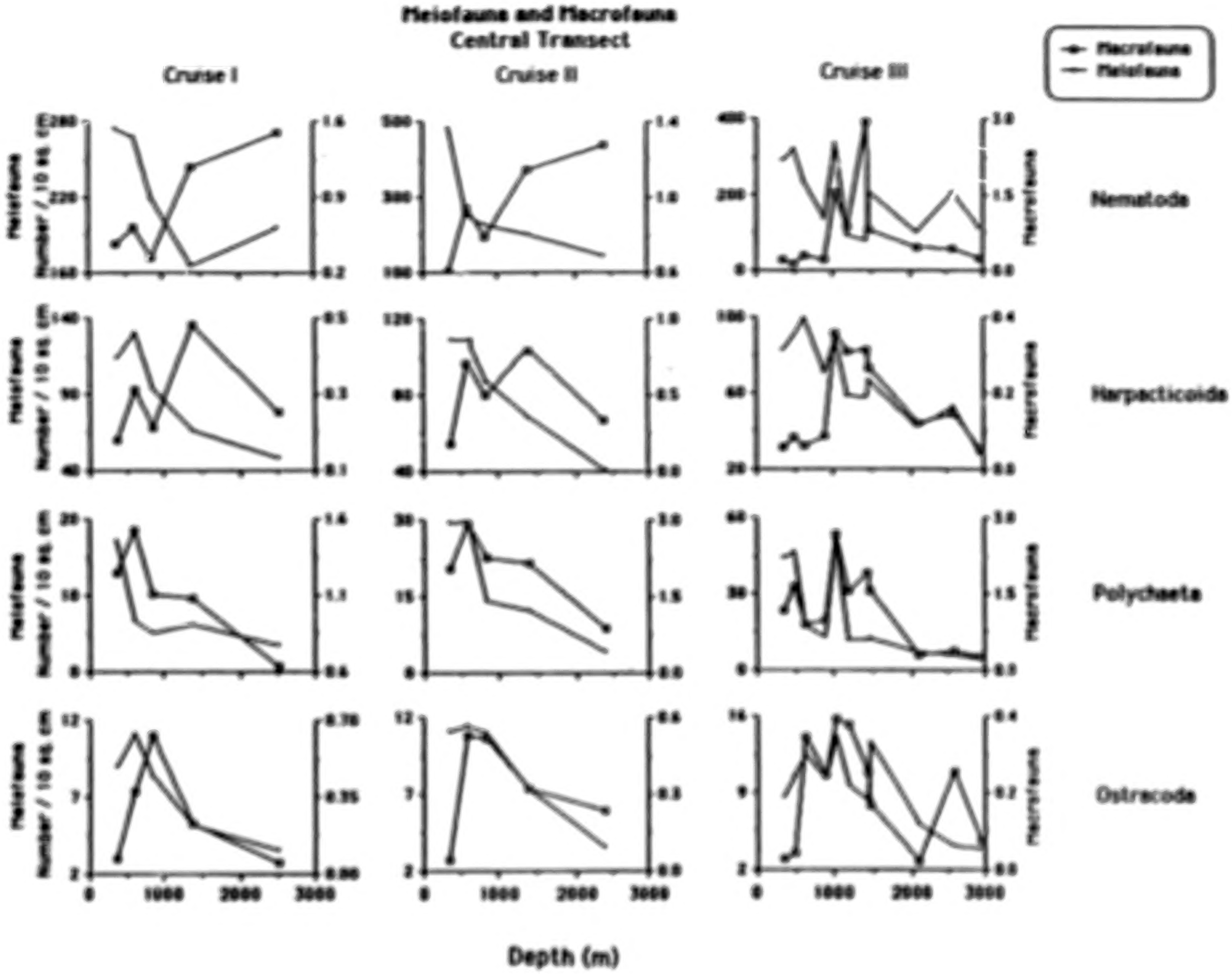


Figure 4-12. Comparison of macrofauna and meiofauna densities for four major infaunal groups. Meiofauna densities are one to two orders of magnitude greater than macrofauna densities.

I and III are as great as the down-slope differences. Moreover, during Cruise III, which sampled the slope at finer depth-intervals, significant exceptions to the trend of decreasing density were observed (depths of 1021, 1465, and 2518 m; Stations C7, C4, and C5, respectively).

Sediments from two of these stations, C7 and C5, had markedly lowered values of the carbon preference index (see Section 3.2.2.3, this volume) indicating hydrocarbon enrichment in the surface sediments. Benthic photographs at Station C7 revealed a dense community of chemosynthetic clams in the surface sediments at this location (Rosman et al. in press). Other investigations of Gulf of Mexico meiofaunal densities have shown that localized chemical enrichment of surface sediments can provide the basis for a chemosynthetic food-web that causes a general increase in infaunal density and diversity (Powell et al. 1986). Similar processes seem to have been observed during the Cruise III sampling.

Comparison of the Eastern Transect collection from Cruise IV (Fig. 4-4) shows that the variability within isobaths can be as great as the differences between isobaths. Although the depth range of the Eastern Transect stations was identical to that of the Central Transect stations, the decreasing trend is much less clear in the Eastern Transect collections. The primary differences between these two transects were variability in sediment grain size, steepness of the slope, and the presence of hydrocarbon seeps on the Central Transect. The slope of the Central Transect was more or less constant between 300 and 3000 m depth; sediments were predominantly clay, becoming gradually coarser with increasing depth. The slope of the Eastern Transect was quite gradual to a depth of 1000 m and then dropped abruptly at the edge of the Florida Escarpment; sediments were variable, but generally coarser than on the Central Transect. The variation in sediment grain size within the Cruise IV sampling isobaths was as great as was seen over the entire depth range on the Central Transect (see Section 3.2). The exact relationship between sediment grain size and meiofauna abundance is not defined by this comparison; however, variability in grain size within isobaths was accompanied by variable meiofauna abundance.

Comparison of the composition of the meiofauna (Figs. 4-7 through 4-11) shows that although the ranking of the six most abundant groups generally remained constant, there was substantial variation in their relative abundance. Sediment characteristics may influence the composition of the meiofauna in predictable ways. Studies in coastal habitats have indicated that sediment grain size influences the relative abundance of nematodes and harpacticoids (Tietjen 1969, Coull 1970). Because these were the most abundant groups found in the present collections, changes in their relative density would influence the overall meiofaunal density. Figure 4-13 shows a comparison of the abundance of nematodes and harpacticoids plotted against percent sand and percent clay. Linear regression of these points shows that the abundance of both groups decreased as the sediments became coarser, and increased as they became finer. The rate of change was more acute for the nematodes than for the harpacticoids, particularly in the case of increasingly sandy sediments. The fit of these regressions are poor, however, which suggests that other factors also influenced the composition of the meiofauna. More powerful statistical techniques, such as principal component analysis, may prove useful for analysis of these data.

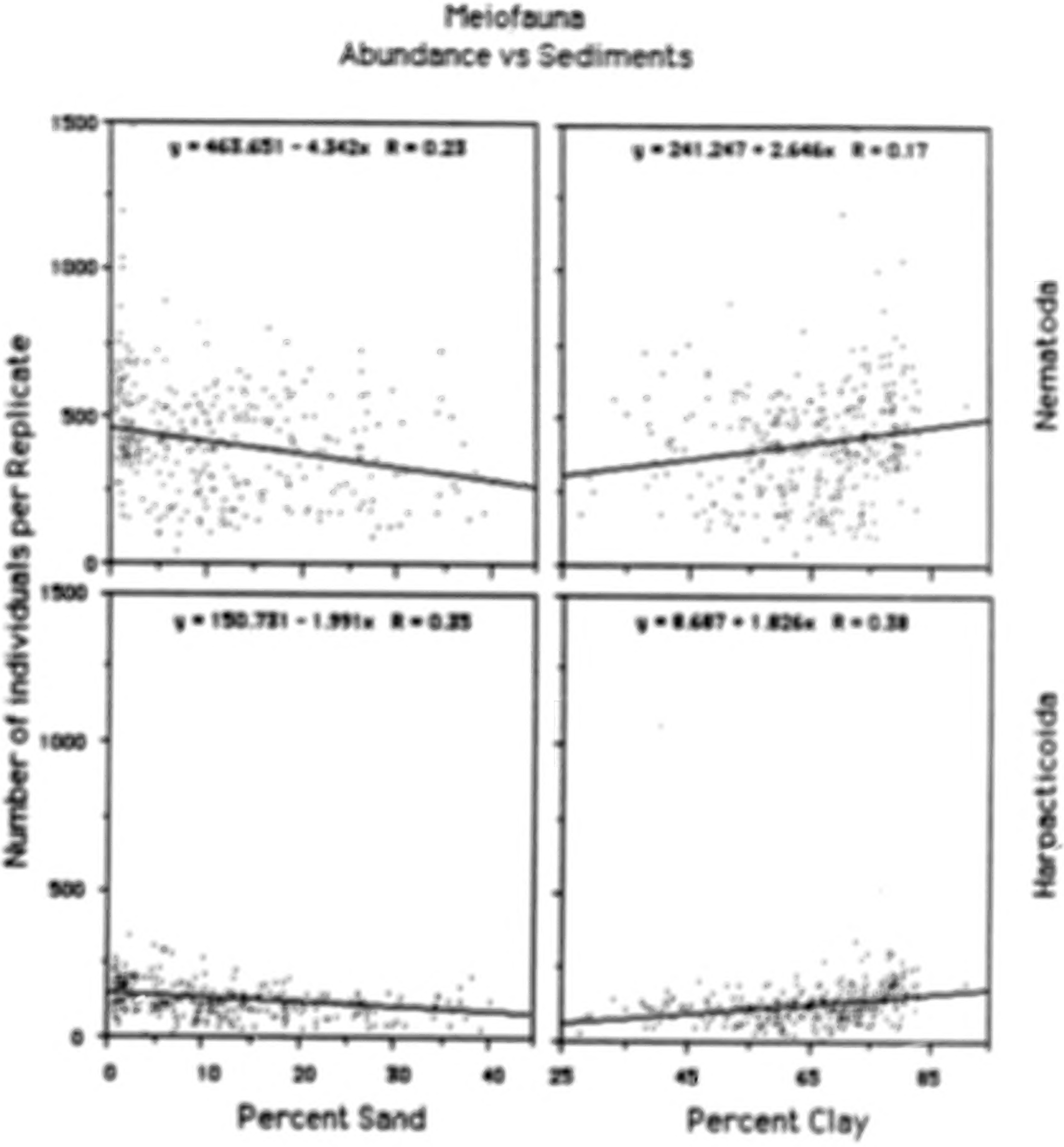


Figure 4-13. Abundance of Nematoda and Harpacticoida plotted against percent sand and clay.

4.2 MACROFAUNA

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4.2 MACROFAUNA

4.2.1 INTRODUCTION

Macrofauna was defined for the purposes of this study as those organisms collected with box corers and retained on a 0.3 mm sieve and thus represent much smaller sizes than one typically finds in other macrofauna samplings which have used 0.5 mm or 0.42 mm sieves. Three general sampling strategies were employed to examine macrofaunal distributions:

1. Cruises I through III sampled down-slope (across isobaths) in three different areas (central, eastern, and western transects) and two seasons, in order to study depth-related changes in macrofauna in various parts of the Gulf;
2. Cruise IV sampled parallel to isobaths of the eastern transect, in order to focus upon variability independent of depth; and
3. Cruise V also sampled along isobaths with emphasis placed on areas of special biological interest in the area between the western and central transects.

Samples from the macrofaunal component of box cores contained 18 phyla, which were separated into 1569 differentiable taxa. Specimens were routinely identified to the lowest possible taxon, except for those belonging to four major groups in which severe taxonomic difficulties were encountered: Nematoda, Copepoda (primarily harpacticoid copepods), Aplacophora, and Scyphozoa.

Nematodes and copepods, although often retained in large numbers in the macrofaunal sieve, more appropriately should be treated with the meiofauna. In this report we describe the nematode and copepod densities contained within the macrofaunal collections but do not include their numbers in the overall density or diversity estimates. Neither do we attempt to identify them below nematode or copepod designations.

Most scyphozoans were collected in the strobila stage. Taxonomic keys for the strobila of deep-sea scyphozoans are virtually nonexistent. Aplacophorans require complex preparatory procedures before they can be examined properly, and are poorly described at best. Balancing the potential costs against the chances of successful identification of lower taxa within these groups of organisms, LGL and MMS decided to allocate the project's resources in favor of more tractable groups.

Species-level identification was attempted for the remaining groups of macrofauna. For these groups, approximately 89% of the individuals were identified either to genus or to species; 71% of the taxa were identified to species. Specimens that could not be identified to species were usually either a) juveniles that had not yet developed the requisite taxonomic characteristics, or b) specimens that no longer possessed in an intact form the morphological structures necessary for positive identification. Loss through autotomy or damage to some structures (e.g. microscopic appendages on crustaceans) is an unavoidable consequence of collection and preservation for some of the more delicate species, no matter how carefully the samples are handled. The small sizes of the macrofaunal specimens from this study were remarked upon by most of the taxonomic specialists, making identification to the lower taxonomic levels much more difficult because in most cases the small sizes represented immature specimens.

4.2.2 COMMUNITY STRUCTURE

Table 4-2 lists the 40 major macrofaunal groups in decreasing order of total numerical abundance over all five cruises, for all stations together. It also gives information on number of taxa identified in each group, and relative numbers of taxa identified to the specific, generic, and higher taxonomic levels.

Specimens belonging to the first 20 groups accounted for 99% of the total number of individuals collected. Six taxonomic groups (Polychaeta, Ostracoda, Bivalvia, Tanaidacea, Bryozoa, and Isopoda) accounted for 86% of the total numerical abundance. Counts of bryozoans mainly included single, more-or-less intact colonies. An attempt was made to avoid overestimating bryozoan abundance by not counting multiple, broken pieces

Table 4-2. Relative abundance of major macrofaunal groups.

Taxonomic group	No. Individuals	Total No. Individual Forms	No. Iden. To Species	No. Iden. To Genus	No. Iden. To Family Or Higher Taxa
POLYCHAETA	24513	626	414	163	49
OSTRACODA	4960	19	18	1	0
BIVALVIA	3645	55	41	10	4
TANAIDACEA	3610	186	168	13	5
BRYOZOA	3049	99	82	12	5
ISOPODA	2327	133	119	8	6
AMPHIPODA	1285	79	50	11	18
APLACOPHORA	886	1	0	0	1
NEMERTEA	630	21	20	0	1
OPHIUROIDEA	603	17	13	3	1
SIPUNCULA	570	37	31	3	3
CUMACEA	521	86	76	8	2
PORIFERA	424	39	22	10	7
SCAPHOPODA	382	10	5	2	3
SCYPHOZOA	331	1	0	0	1
GASTROPODA	276	53	8	27	18
HOLOTHUROIDEA	250	13	4	4	5
OLIGOCHAETA	247	9	6	1	2
ASCIDIACEA	136	18	11	3	4
HYDROZOA	103	15	8	3	4
BRACHIOPODA	79	2	2	0	0
ARACHNIDA:ACARINA	62	1	0	0	1
KINORHYNCHA	60	3	0	2	1
ECHINOIDEA	49	6	3	1	2
PRIAPULIDA	33	1	0	0	1
SCLERACTINEA	33	6	4	1	1
DECAPODA	25	13	10	1	2
MYSTACOCARIDA	12	1	0	0	1
POGONOPHORA/VESTIMENT.	11	1	0	0	1
ECHIURA	9	1	0	0	1
ACTINIARIA	8	3	0	0	3
ALCYONARIA	8	2	1	0	1
TURBELLARIA	8	1	0	0	1
CRINOIDEA	7	2	2	0	0
PYCNOGONIDA	7	3	3	0	0
HEMICHORDATA	4	1	0	0	1
ASTEROIDEA	2	2	0	1	1
MISC. ANTHOZOA	2	1	0	0	1
MYSIDACEA	2	1	0	0	1
ARCHIANNELIDA	1	1	0	0	1
Total	**48970**	**1569**	**1121**	**288**	**160**

of colonies. At the species level, most macrofaunal taxa were represented by very few individuals (Fig. 4-14). For example, over 550 species, excluding the polychaetes, were collected five or fewer times (only 1 to 5 individuals total, for all samples combined).

Table 4-3 lists in rank order the dominant 50 species occurring at all macrofaunal stations combined. The list includes 28 species of polychaetes, six bivalve mollusks, three species of ostracods, two isopods, two amphipods, one sponge, and one nemertean worm.

4.2.3 MACROFAUNA ABUNDANCE PATTERNS

Based upon preliminary calculations, the overall density levels of macrofauna among study area sampling stations (not including nematodes, non-myodocopan ostracods and copepods, considered meiofauna) ranged from about 518 specimens/m^2 (Station C12, Cruise III) to 5369 specimens/m^2 (Station E2E, Cruise IV). As noted, these overall density estimates are preliminary. Other than excluding some obvious meiofaunal forms retained on occasion in the macrofauna sieve, we have not, as yet, examined the collection lists and deleted other forms that should not, by convention, be included in our macrofauna designation. These changes, once made, are not expected to have any detectable effects on the overall abundance trends.

The overall region, season, year by depth patterns of macrofaunal abundance are shown by Figure 4-15. From inspection, abundance appears somewhat higher on the Central Transect ($\bar{x}$=3156/m^2) than on either the Eastern ($\bar{x}$=2695/m^2) or Western Transects ($\bar{x}$=2100/m^2). Based upon the data from the Central Transect, spring abundance levels (3156/m^2) appeared higher than fall abundance levels ($\bar{x}$ ranged from 1657 to 1987/m^2). The annual differences between the fall collections of 1983 and 1984 on the Central Transect and the spring collections of 1984 and 1985 on the Eastern Transect were 330 and 169/m^2, respectively. This compares to regional differences ranging between 461 and 1056/m^2, and seasonal differences ranging from 1169 to 1499/m^2. Annual differences appear less than regional and seasonal variation in abundance.

On both the Eastern and Western Transects, an overall decline of macrofaunal density with depth is clearly indicated, even though there are

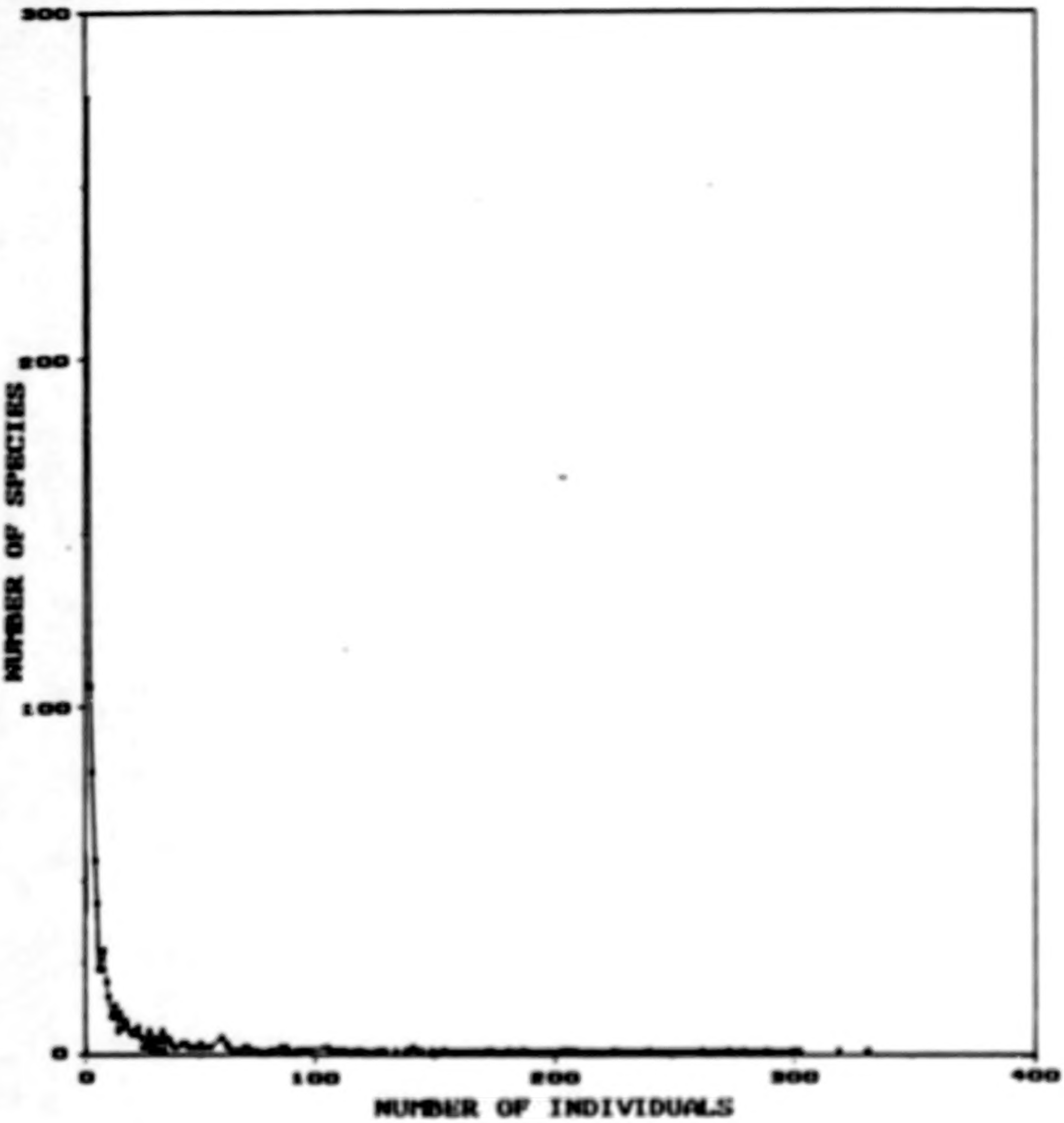

Figure 4-14. Plot of number of macrofaunal species versus number of individuals showing the great number of species that were collected few times compared to the fewer species that occurred in large numbers.

Table 4-3. Rank order of dominant macrofaunal species.

SPECIES	GROUP	OVERALL DENSITY (no/m²)	NO. OF INDIVIDUALS	NO. OF STATIONS	DEPTH RANGE (m)
Nolella monniotae	Bryozoa	112	1772	27	298-2901
Litocorsa antennata	Polychaeta: Pilargidae	78	1209	30	298- 881
Aurospio dibranchiata	Polychaeta: Spionidae	77	1190	49	298-2827
Maldane sp.	Polychaeta: Maldanidae	46	715	15	298-1465
Aedicira sp.	Polychaeta: Paraonidae	44	679	53	298-2945
Tachytrypane sp. A	Polychaeta: Opheliidae	37	571	51	298-2518
Spiophanes berkeleyorum	Polychaeta: Spionidae	33	505	52	298-2901
Exogone "sp. A"	Polychaeta: Syllidae	30	467	53	346-2945
Aricidea suecica	Polychaeta: Paraonidae	27	421	54	298-2945
Pholoe "sp. C"	Polychaeta: Sigalionidae	27	417	29	346-1021
Maldane "sp. A"	Polychaeta: Maldanidae	26	402	16	298-1465
Prionospio ehlersi	Polychaeta: Spionidae	24	380	37	344-1465
Levinsenia gracilis	Polychaeta: Paraonidae	24	371	53	298-2945
Euphilomedes sp. A	Crustacea: Ostracoda	21	332	23	453- 860
Eulamellibranchia sp. F	Mollusca: Bivalvia	20	319	34	298- 860
Pseudotanais sp. 1	Crustacea: Tanaidacea	19	299	52	298-2945
Euginoma cavalieri	Bryozoa	18	289	37	298-2506
Fauveliopsis sp. B	Polychaeta: Fauveliopsidae	18	283	49	298-2945
Angulorostrum sp. A	Crustacea: Ostracoda	18	279	44	298-1465
Sarsonuphis hartmanae	Polychaeta: Onuphidae	18	276	49	298-1465
Nolella sp.	Bryozoa	17	273	22	353-2945
Prionospio cirrifera	Polychaeta: Spionidae	18	272	30	298-2506
Vesicomya sp.	Mollusca: Bivalvia	17	262	40	344-2389
Malletia sp. B	Mollusca: Bivalvia	15	239	39	298-1381
Tharyx marioni	Polychaeta: Cirratulidae	15	231	52	298-2945
Lumbrinerides dayi	Polychaeta: Lumbrineridae	15	229	48	298-2945
Crenella sp. A	Mollusca: Bivalvia	14	225	34	547-1465
Ceratocephale oculata	Polychaeta: Nereidae	14	220	45	339-2901
Paralacydonia paradoxa	Polychaeta: Lacydoniidae	14	211	37	298-1390
Nucula sp. A	Mollusca: Bivalvia	13	208	46	339-1465
Philomedes sp. A	Crustacea: Ostracoda	13	203	19	346- 838
Leitoscoloplos sp. A	Polychaeta: Orbiniidae	13	196	20	298-1430
Tharyx cf. annulosus	Polychaeta: Cirratulidae	12	191	42	298-2901
Paramphinome jeffreysii	Polychaeta: Amphinomidae	12	188	47	298-2475
Neotanais sp. 1	Crustacea: Tanaidacea	11	181	34	339-1390
Leptognathia sp. 15	Crustacea: Tanaidacea	11	173	37	344-2901
Terebellides stroemi	Polychaeta: Trichobranchidae	11	173	35	298-2518
Diplocirrus capensis	Polychaeta: Flabelligeridae	11	168	42	298-2389
Pionosyllis "sp. H"	Polychaeta: Syllidae	10	161	27	298-1021
Apseudidae A	Crustacea: Tanaidacea	10	154	19	359-1465
Aricidea sp.	Polychaeta: Paraonidae	10	155	41	298-2518
Terebellides atlantis	Polychaeta: Trichobranchidae	10	153	32	339-1465
[illegible] sp. 201	Crustacea: Isopoda	9	149	9	344-1226
Pardaliscopsis n. sp. 1	Crustacea: Amphipoda	9	145	36	547-2901
Phoxocephalidae sp. 1	Crustacea: Amphipoda	9	143	30	298-1465
Ischnomesus sp. 208	Crustacea: Isopoda	9	141	28	453-1381
Cuspidaria sp.	Mollusca: Bivalvia	9	141	33	298-2945
Stelletta sp.	Porifera	8	134	25	298-1465
Nemertea sp. CL4	Nemertea	8	130	47	298-2827
Spionidae Genus B	Polychaeta: Spionidae	10	130	14	298- 759

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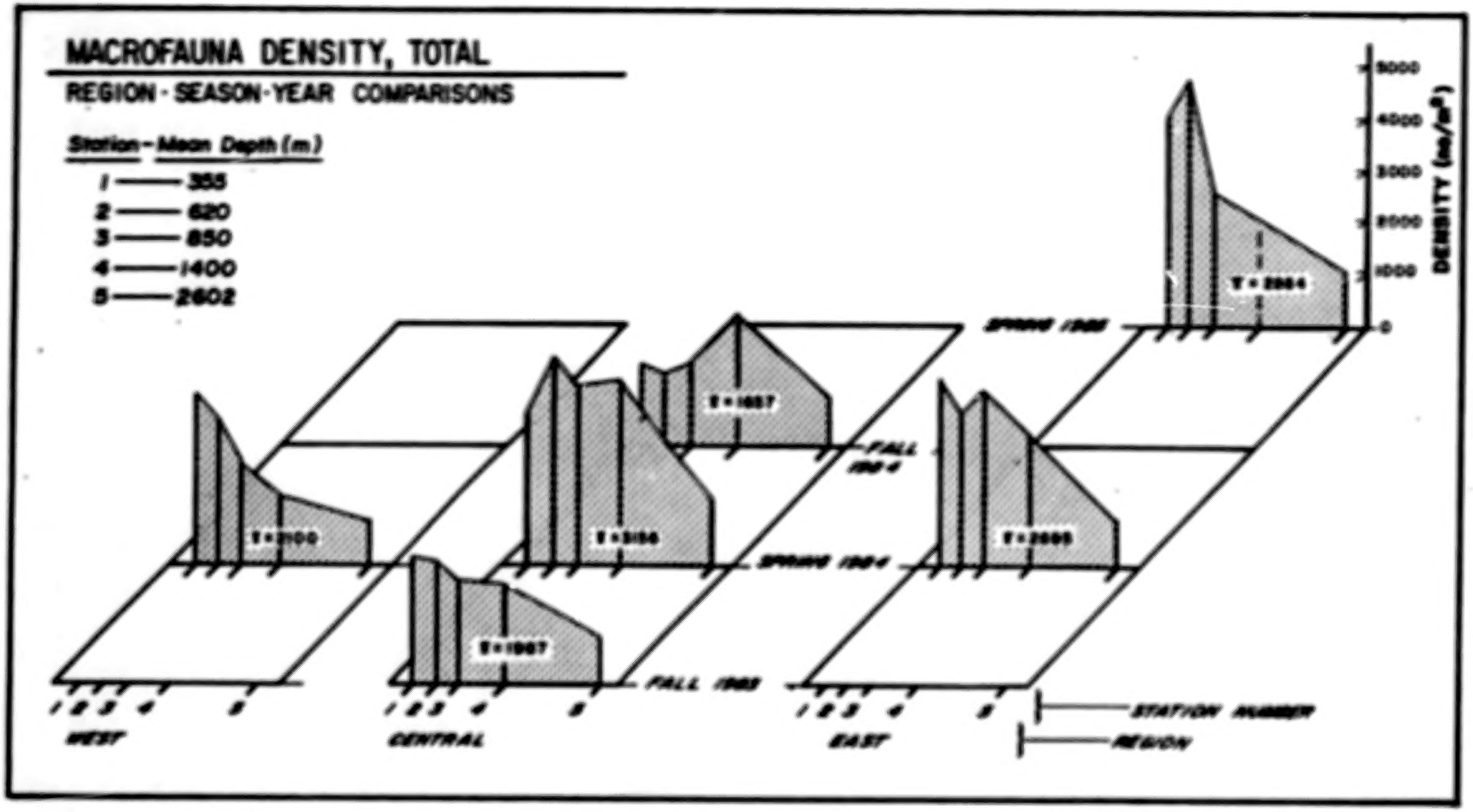

Figure 4-15. Comparative levels of macrofaunal densities by region, season, year and selected depth interval.

some exceptions at the shallower of the sampled depths (Fig. 4-15). On the Central Transect, the observed trend of abundance decrease with depth is interrupted by an apparent abundance peak at the 1400-m deep station. Increased sampling intensity on the Central Transect, not only validated the 1400-m peak, but yielded data suggesting even higher abundance was present at about 1000-m depths (Fig. 4-16). These apparent differences will be examined in detail in the Year 4 Final Report. Suffice it to say now that we believe the "anomalous" abundance peaks to be related to physiography and/or proximity to chemosynthetic seep communities.

Results of sampling along isobaths in both the Eastern (Fig. 4-17) and Western (Fig. 4-18) Transects yielded consistent results in terms of overall density, except for some of the planned contrasts of sediment type, proximity to seep communities and topographic features. The exceptions were unexpected low densities at Stations E2D and E3 on the Eastern Transect. All of these differences (those accountable by design and those unexpected) will be evaluated in the Year 4 Annual Report.

4.2.4 MACROFAUNA DIVERSITY PATTERNS

The diversity evaluations made in this report are based upon comparisons of the H' index applied to data for species only. From review of these data and supporting indices (evenness and richness) it is apparent that most of the differences in the overall index are attributable to the richness aspect, which is greatly influenced by sample size. In the Year 4 report, rarefaction analysis will be used to offset the confounding effects of sample size on the diversity evaluations.

The regional, seasonal and yearly patterns of macrofaunal diversity by depth are presented in Figure 4-19. Although the trends are not pronounced, diversity appears to decrease from east to west and to have been somewhat higher in fall than in spring on the Central Transect. Differences in fall diversity levels between years on the Central Transect were negligible, but spring 1985 diversity levels on the Eastern Transect were marginally higher than spring 1984 levels (Fig. 4-19).

The most consistent depth trend was a marked decrease in diversity between the 1400-m deep and 2600-m deep stations on each transect. There also appears a tendency of a slight diversity increase between the

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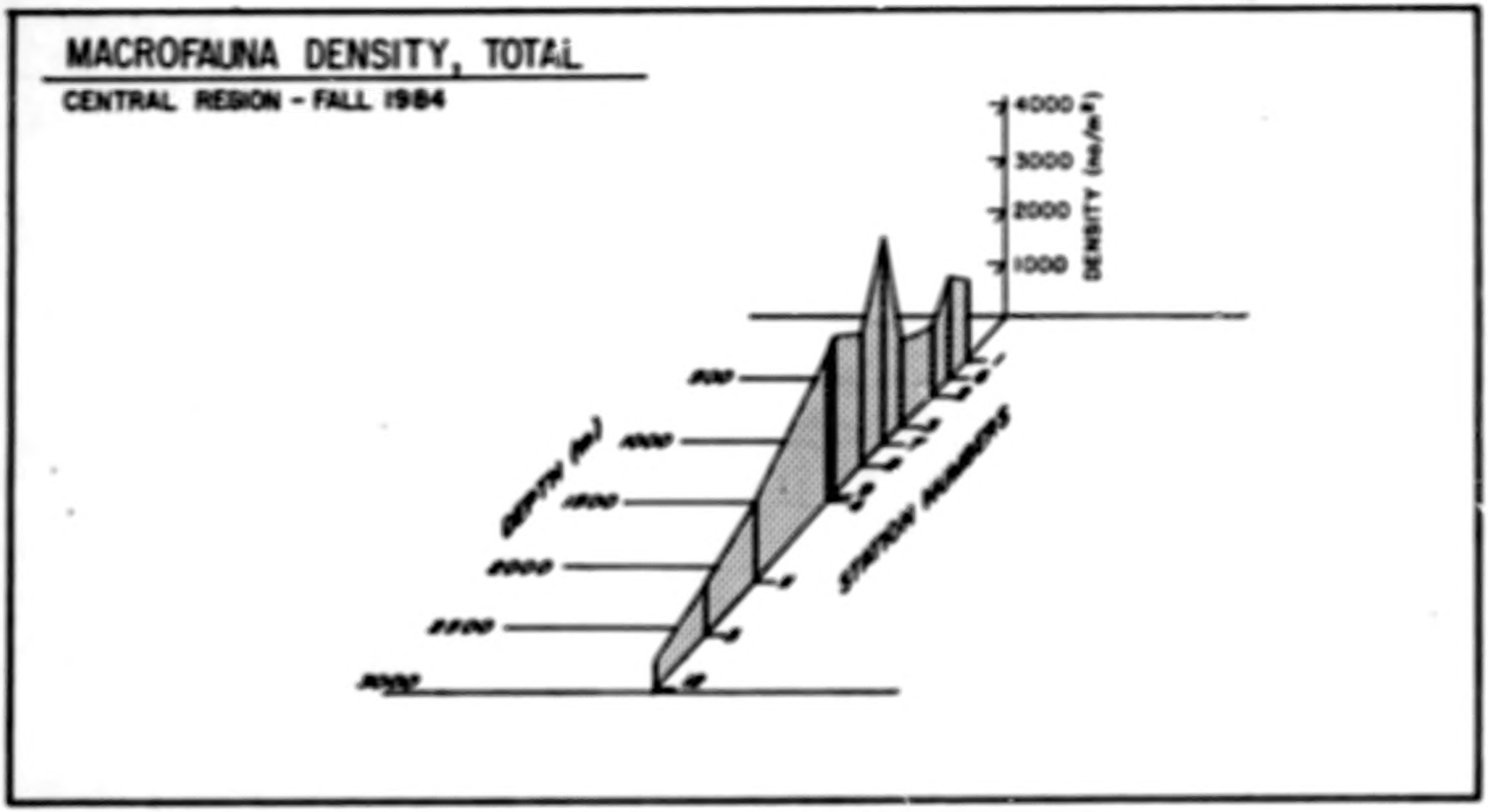

Figure 4-16. Comparative levels of macrofaunal density by depth on the Central Transect, Fall 1984.

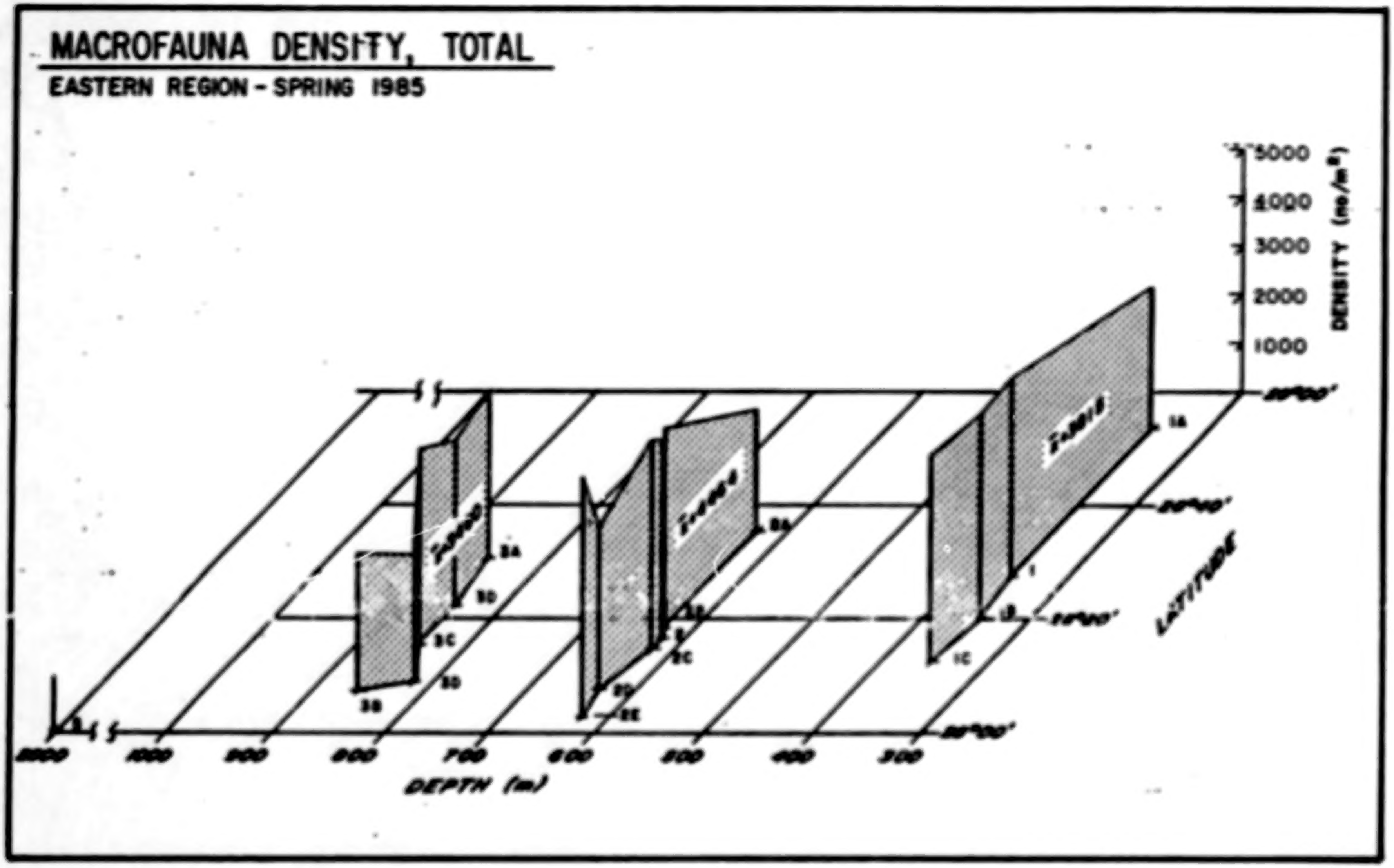

Figure 4-17. Comparative levels of macrofaunal density along selected isobaths in the Eastern Gulf of Mexico during Spring 1985.

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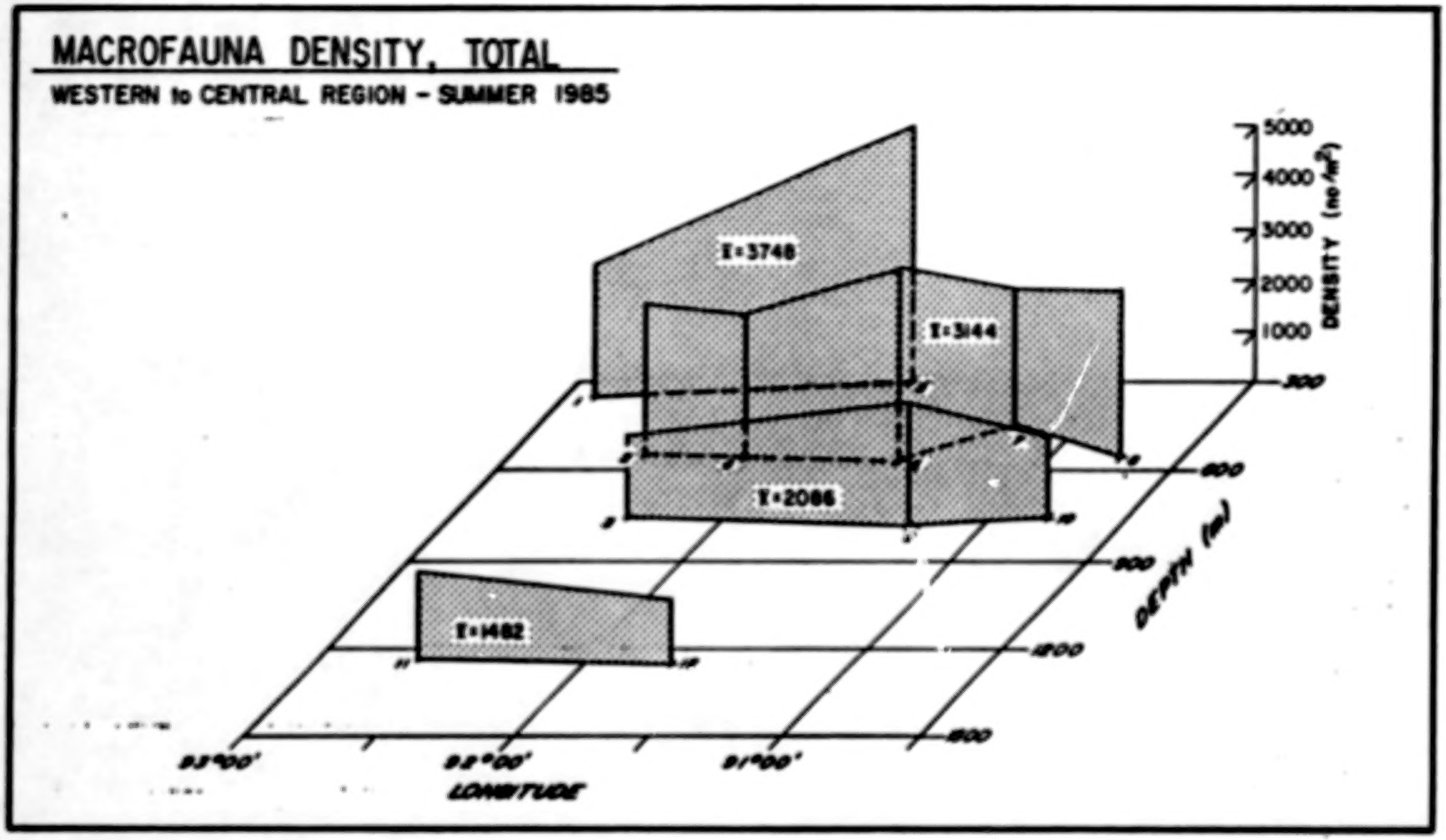

Figure 4-18. Comparative levels of macrofaunal density along isobaths between the Central and Western Gulf of Mexico sampling transects, Summer 1985.

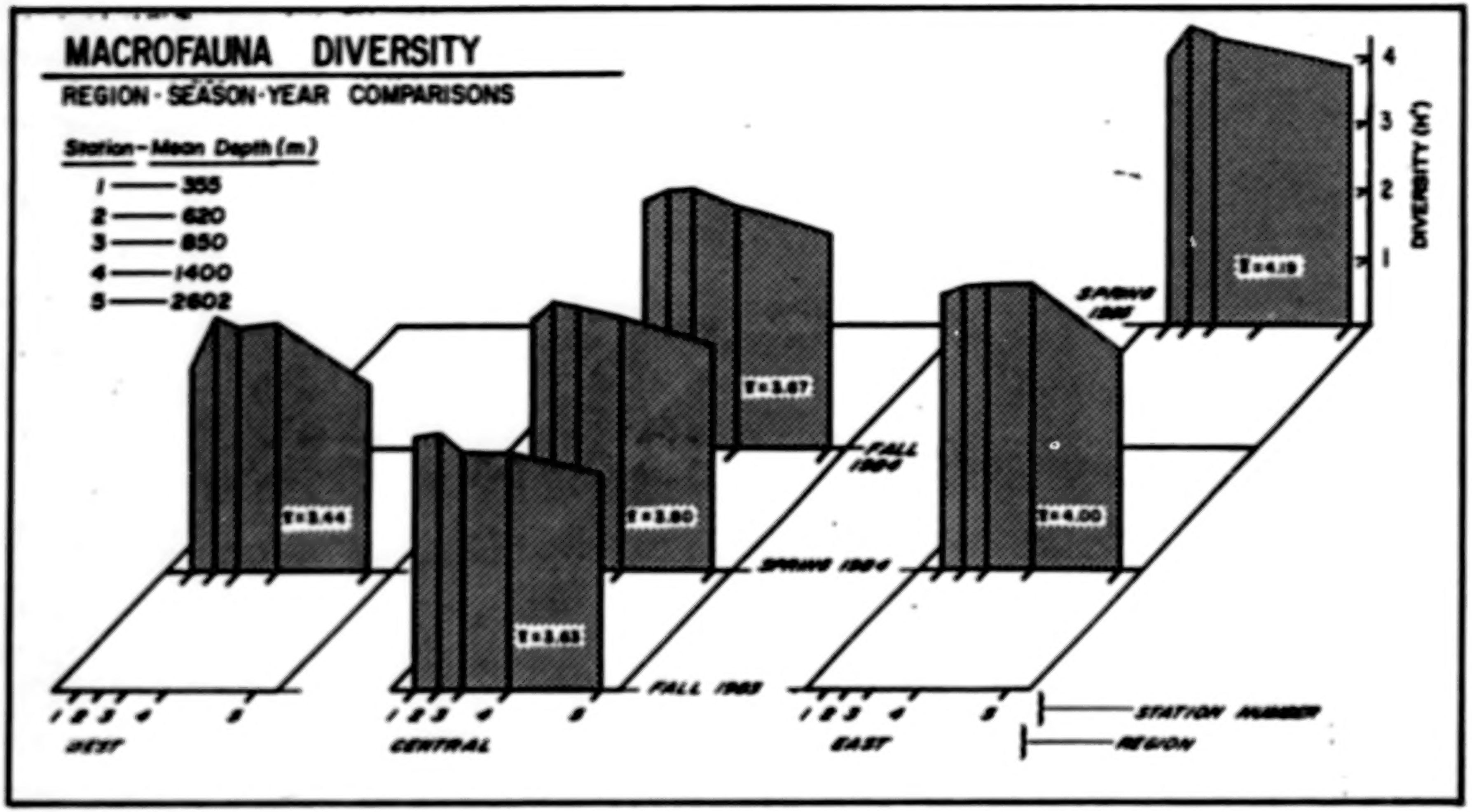

Figure 4-19. Comparative levels of macrofaunal diversity by region, season, year and selected depth interval.

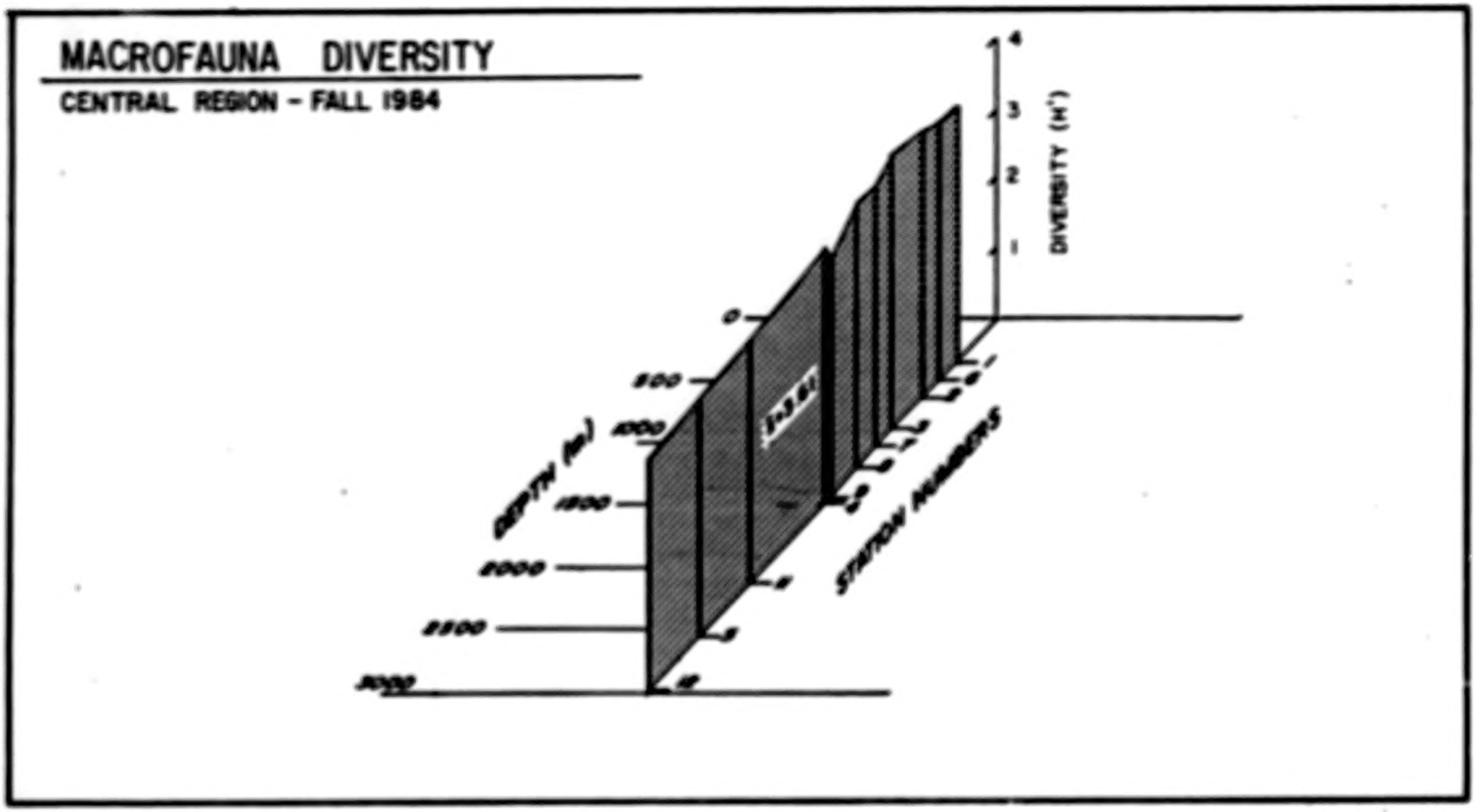

Figure 4-20. Comparative levels of macrofaunal diversity by depth on the Central Transect, Fall 1984.

shallowest station (~350 m) and some of the sequentially deeper stations, yielding somewhat skewed, dome-shaped diversity curves over the depth range sampled.

The data obtained from sampling a higher density of stations on the Central Transect in fall 1984 enabled a more detailed examination of macrofauna diversity levels over the sampled interval (Fig. 4-20). Diversity appeared to increase slightly from Station 1 (355 m deep) to Station 3 (850 m deep), and from there decreased with depth down to Station 9 (1428 m deep). A slight peak was observed at Station 4 (1465 m deep), after which the diversity level once more declined gradually over the depth interval between 1465 m and 2945 m (Fig. 4-20).

As shown by Figures 4-21 and 4-22, macrofauna diversity levels were rather constant along the sampled isobaths in both the eastern and western regions where these studies were conducted. Additionally, there appeared very little variation by depth, at least within the intervals sampled.

4.2.5 MAJOR GROUP ACCOUNTS

The 32 macrofaunal groups discussed below account for 99.9% of the total macrofauna by abundance. The groups are arranged essentially in phylogenetic order (i.e., in order of NODC code numbers) and not in order of greatest abundance in the macrofauna. For this report, some groups which are not usually treated with macrofauna are included for convenience as they will not be discussed elsewhere. The following 32 groups are discussed below in this order: Porifera, Hydrozoa, Scyphozoa, Actiniaria, Alcyonaria, Scleractinia, Nemertea, Kinorhyncha, Nematoda, Polychaeta, Oligochaeta, Gastropoda, Aplacophora, Bivalvia, Scaphopoda, Acarina, Ostracoda, Copepoda, Cumacea, Tanaidacea, Isopoda, Amphipoda, Decapoda, Pogonophora/Vestimentifera, Sipuncula, Priapulida, Bryozoa, Brachiopoda, Ophiuroidea, Echinoidea, Holothuroidea, and Ascidiacea.

Of the 18 taxonomic groups for which highest and lowest total transect diversities (i.e., number of taxa at all stations on the transect) were figured, 61% (11) had their greatest diversity at the Eastern Transect on Cruise IV and 61% (11) had their lowest diversities at the Western Transect. Likewise, of the 26 macrofaunal groups for which mean transect densities were calculated, 54% (14) of the groups had their

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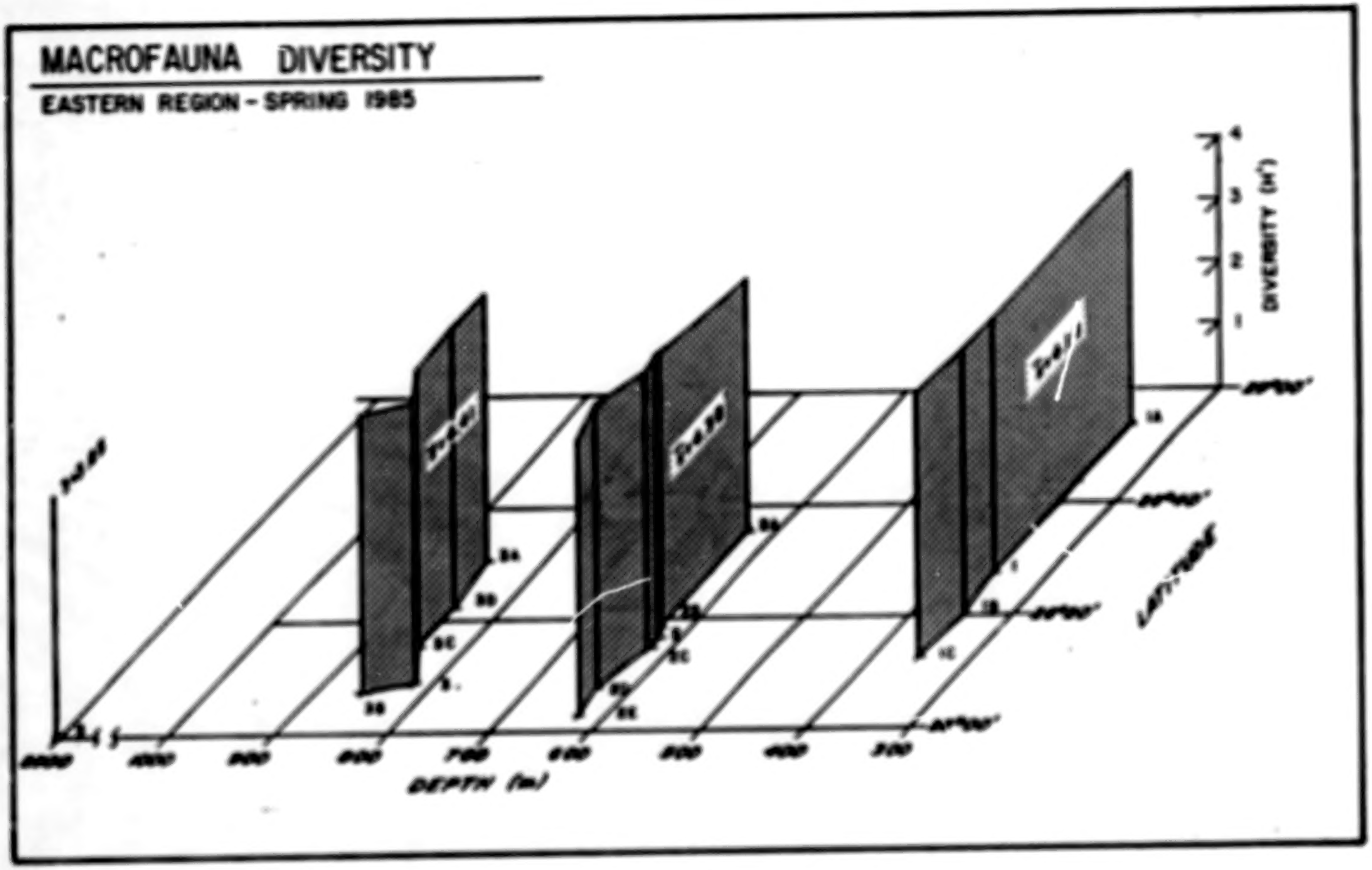

Figure 4-21. Comparative levels of macrofaunal diversity along selected isobaths in the Eastern Gulf of Mexico during Spring 1985.

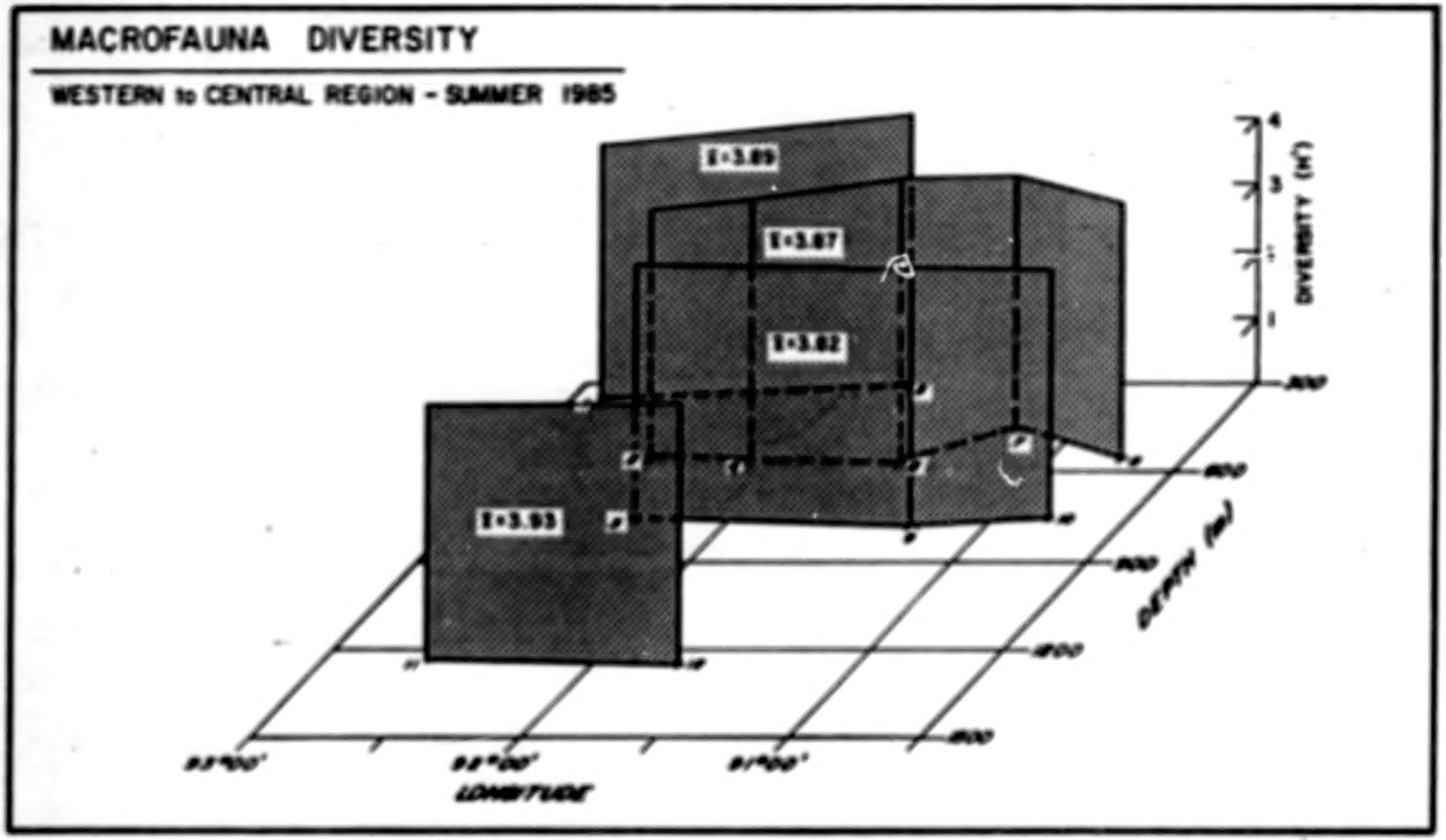

Figure 4-22. Comparative levels of macrofaunal diversity along isobaths between the Central and Western Gulf of Mexico sampling transects, Summer 1985.

highest mean transect densities at the Eastern Transect on Cruise IV while 46% (12) had their lowest mean densities on the Western Transect. Another 31% (8) had their lowest densities on the Central Transect on Cruise III. The reasons for this can only be speculated at this time, and will be dealt with in more detail in the synthesis report.

4.2.5.1 Porifera

Sponges ranked 15th in overall abundance in macrofaunal samples and ninth in total number of taxa. Some 39 taxa were identified, 22 of which were identified to the species level, 10 to the generic level, and seven to family or above.

The number of sponge species ranged from 0-10 taxa at individual stations. Highest species diversity (10 taxa) occurred at Station E5, Cruise IV (2902 m). Highest transect species diversity (21 taxa) was at the Central Transect on Cruise III in November 1984. Lowest transect species diversity for sponges was five taxa at the Central Transect on Cruise I in November 1983.

Sponges in the box core samples consisted of very small, intact colonies or protocolonies and not of pieces broken off from larger sponges. Therefore, the sponge counts and densities are quantitatively reliable.

Sponge densities for each station on all transects from all five cruises are shown in Figure 4-23. Sponge densities ranged from 0 to 137/m^2 with the highest density found at Station E5, Cruise IV (2902 m) (Fig. 4-23). Highest mean transect density, 48/m^2, was at the East Transect on Cruise IV; lowest, 4/m^2, was at the Central Transect on Cruise I.

Mean densities arranged by depth show the following:

Depth (m)	Mean Density (No./m^2)
298- 492	16
500- 900	28
1000-1500	22
2000-2945	50

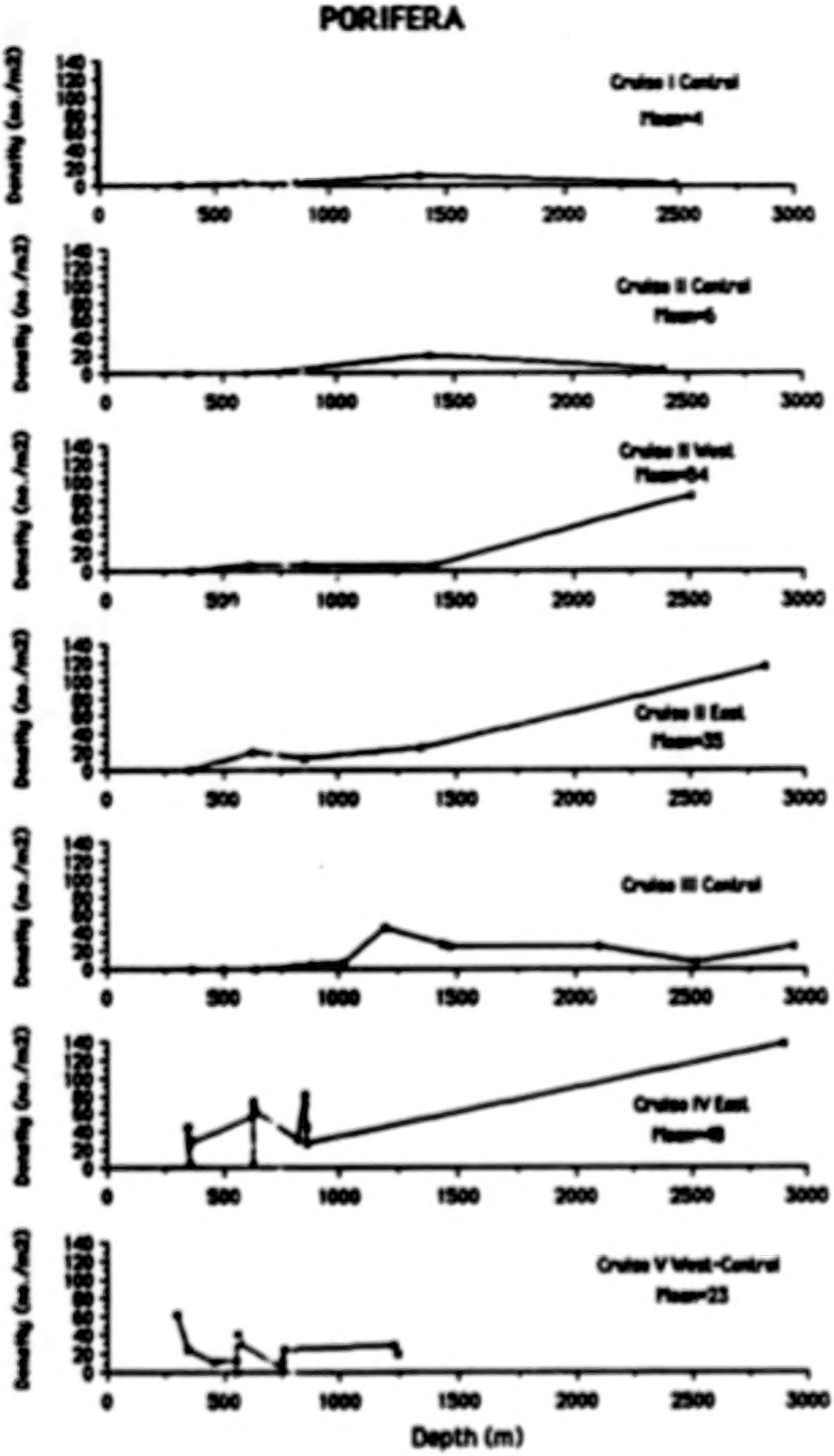

Figure 4-23. Station densities (no/m^2) for Porifera at all transects on all five cruises.

The sponges are one of the few macrofaunal groups (along with the Oligochaeta, Priapulids, and Brachiopoda) that show increased densities at the deepest levels sampled, i.e. below 2000 m depth.

The ten most abundant sponges were:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Stelletta sp.	8.47	134	25	298-1465
Suberitidae sp. B	3.92	62	19	298-2901
Sycon sp.	2.28	36	18	352-2901
Thenea sp. B	1.77	28	8	621-2901
Stylocordyla sp.	1.64	26	6	339-2901
Thenea sp. C	1.20	19	7	1350-2945
Mycale sp. A	0.57	9	7	339-2901
Mycale sp. B	0.51	8	6	613-2945
Suberitidae sp. C	0.51	8	6	298-1430
Microciona sp.	0.51	8	3	298- 759

Most of the more abundant sponge taxa were distributed over a wide depth range, except for *Microciona* sp., which was limited to depths shallower than 800 m.

4.2.5.2 *Hydrozoa*

Hydroids ranked 22nd in overall abundance among the macrofaunal groups and 15th in total number of taxa. Fifteen taxa were identified, eight of which were identified to the species level, and three to the generic level. The others were to family level and above.

The greatest diversity of hydroids was three taxa observed at each of Stations C1, WC5, and WC7. The transect with the greatest number of hydroid taxa was the East Transect on Cruise IV where seven total taxa were distributed among 14 of the 16 stations sampled. No hydroids were collected on the Central Transect on Cruise I or the West Transect on Cruise II.

Hydroids, like the bryozoans, are colonial animals and only colonies or pieces of colonies were counted. As with the bryozoans and sponges, in most cases the hydroids encountered in the macrofauna were small, intact colonies and not broken pieces of larger colonies.

Hydroid densities ranged from 0-98/m^2, with the highest station density observed at Station E1A, Cruise IV at 352 m. Mean transect densities ranged from 0 at the Central Transect (Cruise I) and the West Transect (Cruise II) to 14/m^2 at the East Transect on Cruise II. Overall, hydroid densities were highest at the shallower depths (298-492 m) and lowest at depths greater than 2000 m.

Hydroids for which more than one specimen was collected included:

Taxon	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Eucuspidella sp.	1.07	17	7	352-2901
Halecium sp.	0.44	7	1	453
Corymorphidae sp. 1	0.32	5	3	354- 838
Opercularella sp.	0.32	5	2	846-1021
Aglaophenia latecarinata	0.13	2	1	354
Obelia bidentata	0.13	2	1	633
Cladocarpus flexuosus	0.13	2	2	298- 860

4.2.5.3 Scyphozoa

Scyphozoans were encountered in the macrofauna samples in the benthic strobila stage. They ranked 17th in total abundance of macrofaunal groups. No attempt was made to identify these asexual stages to lower taxonomic levels.

Densities ranged from 0-182/m^2, with the highest station density observed at Station E1A, Cruise IV (352 m). Highest mean transect density for scyphozoans, 39/m^2, occurred on the East Transect on Cruise IV and the lowest, 1/m^2, was encountered on the West Transect.

Mean densities for scyphozoans arranged by depth were:

Depth (m)	Mean Density (No./m^2)
298- 492	56
500- 900	10

Depth (m)	Mean Density (No./m^2)
1000-1500	16
2000-2945	10

All of the higher station densities (greater than 100/m^2) occurred at four of the shallower stations (less than 500 m depth). Even within the shallow depth range of highest mean density, scyphozoan strobila distribution appeared to be very patchy. For example, four of the shallow stations had densities ranging from 0-7/m^2.

4.2.5.4 Actiniaria

Sea anemones in the macrofauna exist as very small juvenile forms that cannot be identified beyond the family, or higher level. Actiniaria ranked 33rd in overall macrofaunal abundance, with only eight individuals taken, primarily at stations deeper than 800 m. They were found only on the Central and East Transects with none taken on the West or West-Central Transects. Highest station density for anemones in the macrofauna was 7/m^2 at Station C4 (1390 m) and E4 (1350 m).

4.2.5.5 Alcyonaria

Alcyonarian corals ranked 34th in overall macrofaunal abundance and occurred only at the East Transect on Cruise IV. Macrofaunal alcyonarians consisted of small, young colonies that were not identifiable except for one specimen of the isidid species, Lepidisis longiflora, taken at Station E3D (849 m). Highest alcyonarian station densities of 7/m^2 were at Station E2A (624 m) and E3 (819 m).

4.2.5.6 Scleractinia

Scleractinian corals ranked 28th in overall macrofaunal abundance and 20th in number of taxa. Six taxa were identified, four of which were identified to the species level. The most abundant taxa of Scleractinia were:

Taxon	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Deltocyathus sp.	0.76	12	4	298-1465
Schizocyathus fissilis	0.70	11	6	298- 621
Deltocyathus calcar	0.38	6	1	298

Highest species diversity was three taxa at Station WC5 (298 m). Highest transect mean diversity for scleractinians, four taxa, occurred on the Central Transect on Cruise III and on the West-Central Transect on Cruise V. No scleractinians were taken on the Central Transect during Cruises I and II, and none were taken on the West Transect.

Scleractinian station densities ranged from 0-63/m^2 with the highest station density occurring at Station WC5, Cruise V (298 m). Highest transect mean density (6/m^2) was observed on the West-Central Transect.

Scleractinians reached their highest mean densities (6/m^2) at the shallowest depths (298-492 m) and then dropped off drastically until there were none taken at stations deeper than 2000 m.

4.2.5.7 Nemertea

Nemertean worms ranked 11th in overall abundance of all macrofaunal groups and 12th in total number of taxa. Twenty-one taxa were recognized, 20 of which were identified to the species level.

The nemertean species have been designated by letters rather than definitive scientific names until it can be determined with certainty which species have been previously described and which are new to science. The top nine nemertean species are listed in order of overall abundance below:

Taxon	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Nemertea sp. C14	8.22	130	47	298-2827
Nemertea sp. D	5.88	93	36	297-2901
Nemertea sp. B	4.93	78	34	298-2475
Nemertea sp. H	1.33	21	13	298-1390
Nemertea sp. E	1.33	21	11	346- 856
Nemertea sp. C15	1.07	17	12	298- 860
Nemertea sp. J	0.89	14	10	298-1465
Nemertea sp. Z	0.89	14	9	352-1021
Nemertea sp. I	0.82	13	9	298-1350

The three most abundant species were found across all depth levels sampled, while three other species appeared restricted to depths shallower than 1500 m and two were found only at depths shallower than 900 m.

The number of Nemertean species per station ranged from 1-10 taxa, with the highest station diversity occurring at WC5 on Cruise V (298 m). Lowest (one taxon) occurred at four stations, all of which were at depths greater than 1400 m. Highest total transect diversity, 17 taxa, occurred on the East Transect on Cruise IV. Lowest transect diversity, six taxa, was at the West Transect on Cruise II.

Nemertean station densities are plotted for all transects and all cruises in Figure 4-24. They ranged from 4/m^2, at Station C12 (2945 m) to 158/m^2 at Station WC5 (298 m). Mean transect density was highest, 57/m^2, for the East Transect on Cruise IV and lowest, 20/m^2, for the Central Transect on Cruise III.

Nemertean mean densities by depth are as follows:

Depth (m)	Mean Density(No./m^2)
298- 492	51
500- 900	44
1000-1500	30
2000-2945	13

There was a decided break in abundance at depths greater than 2000 m as compared to depths 1500 m and shallower.

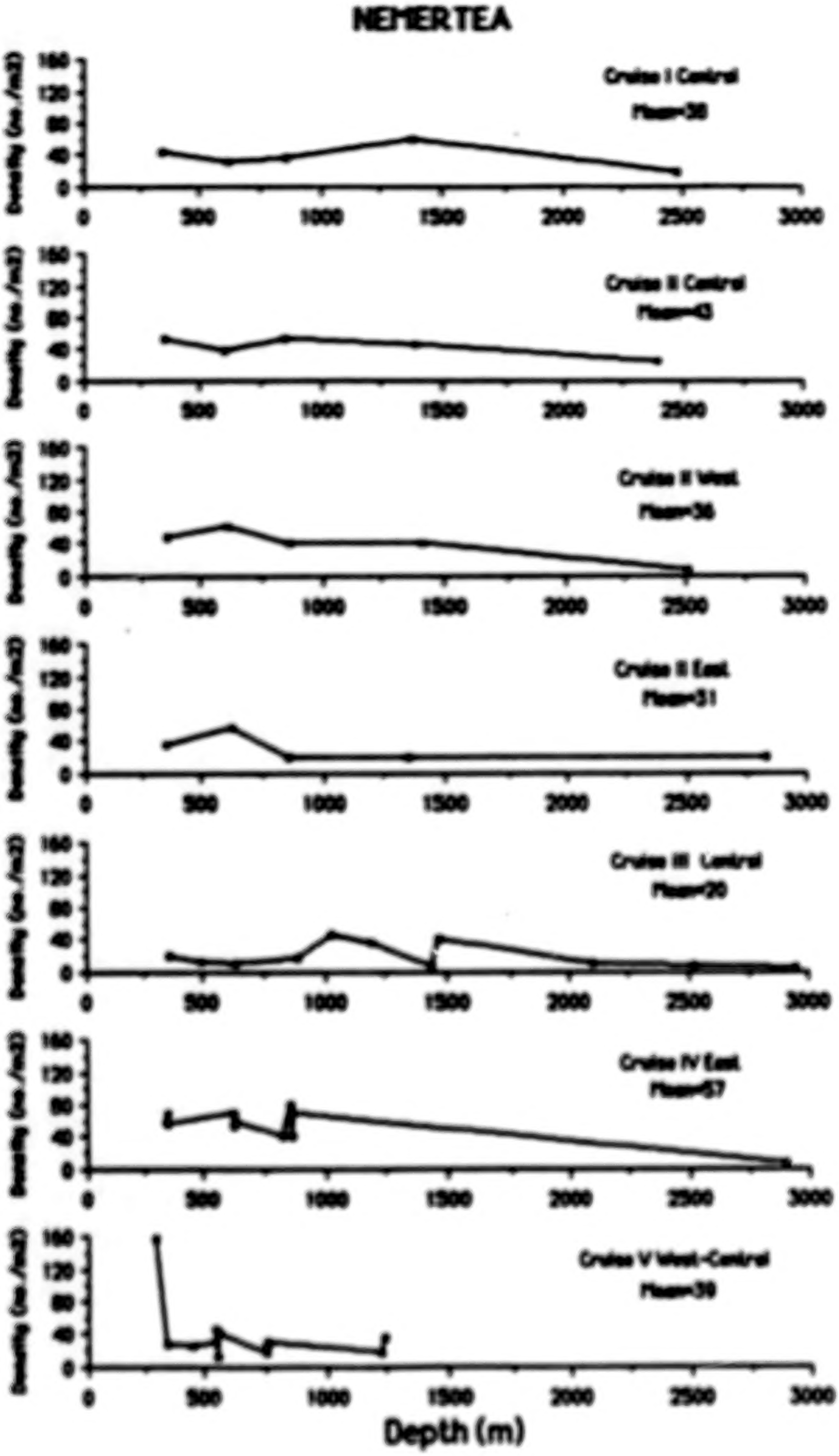

Figure 4-24. Station densities (no/m^2) for Nemertea at all transects on all five cruises.

4.2.5.8 Kinorhyncha

Kinorhynchs are tiny, externally segmented, worm-like organisms which, because of their small size, were found in both the macrofaunal and meiofaunal components of box core samples of this study. Kinorhynchs ranked 25th in overall macrofaunal abundance. Three taxa have been identified from macrofaunal samples, two of which were to the genus level:

Taxon	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Pycnophyes sp.	2.66	42	6	346- 849
Condyloderes sp.	0.06	1	1	345

Total kinorhynch densities ranged from 0-60/m^2, with the highest individual density found at Station E1, Cruise IV (353 m). Highest mean transect density was 10/m^2 noted for the East Transect on Cruise IV. No kinorhynchs were taken on the West or West-Central Transects.

Mean densities of kinorhynch arranged by depth show the following pattern:

Depth (m)	Mean Density (No./m^2)
298- 492	14
500- 900	0.5
1000-1500	3
2000-2945	1

Kinorhynchs join the hydroids, scyphozoans, and scleractinian corals in being the only macrofaunal groups having considerably higher mean densities in the shallowest depths sampled, with abundance dropping drastically at deeper depths.

4.2.5.9 Nematoda

Nematode worms ranked second in abundance after the polychaetes in the macrofauna samples obtained by this study. Nematodes were not scheduled for identification to more specific levels so there are no comparative data for species diversity considerations.

Nematode population densities by station for all five cruises are presented in Figure 4-25. Their station densities ranged from 144-2937/m^2 with the highest density occurring at Station C9, Cruise III (1430 m depth) and the lowest at Station C6, Cruise III (492 m).

The highest mean transect density for nematodes (1520/m^2) was observed for the East Transect on Cruise IV in May 1985 and the lowest (750/m^2) was noted for the Central Transect on Cruise III in November 1984.

Mean densities for nematodes by depth show the following:

Depth Range (m)	Mean Density (No./m^2)
298- 492	1025
500- 900	1198
1000-1500	1156
2000-2945	719

Again, density for depths exceeding 2000 m was markedly lower than density at depths above 1500 m.

4.2.5.10 Polychaeta

A total of 24,313 polychaetes were collected during five cruises sampling at 59 stations. Identifications of the polychaetes included 414 (66%) at the specific level, 163 (26%) to the generic level and 49 (8%) at some higher taxonomic category (usually family), for a total of 626 taxa. Overall, there was an average of 75.7 polychaetes per box core sample representing a density of approximately 1330-1594/m^2.

Densities of polychaetes ranged from 267 to 2905/m^2 at C12 (2951 m, Cruise III) and C2 (597 m, Cruise II), respectively. Densities varied with depth of collection, geographic area and cruise (sampling period). Bathymetric variations were tested specifically on Cruise III when 11 stations were sampled along the central region transect (Fig. 4-26). Within the depth range of 357-1465 m densities ranged from 899 to 2665/m^2 with minimum and maximum at 633 and 1021 m, respectively. Below 2000 m

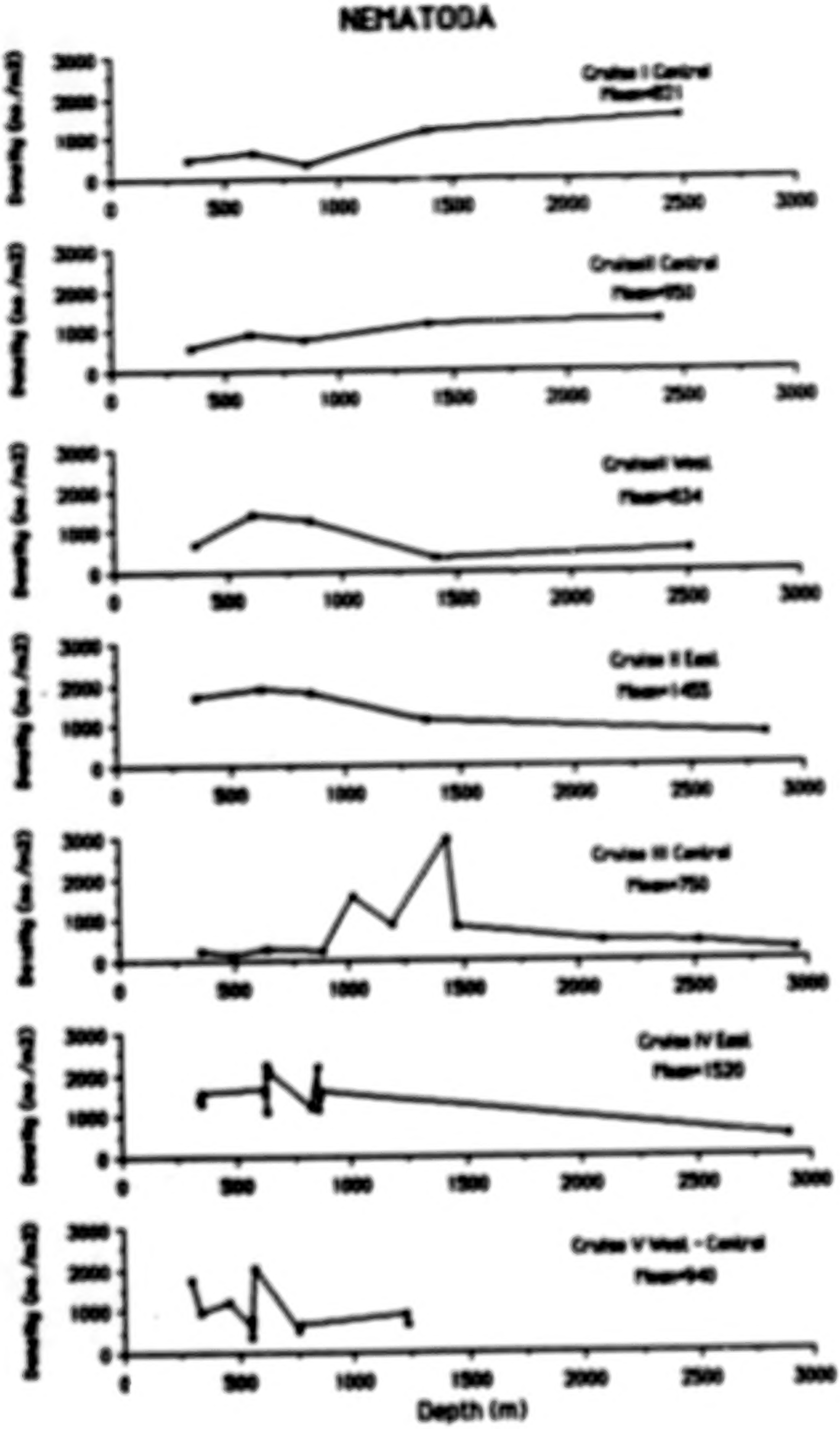

Figure 4-25. Station densities (no/m^2) for Nematoda at all transects on all five cruises.

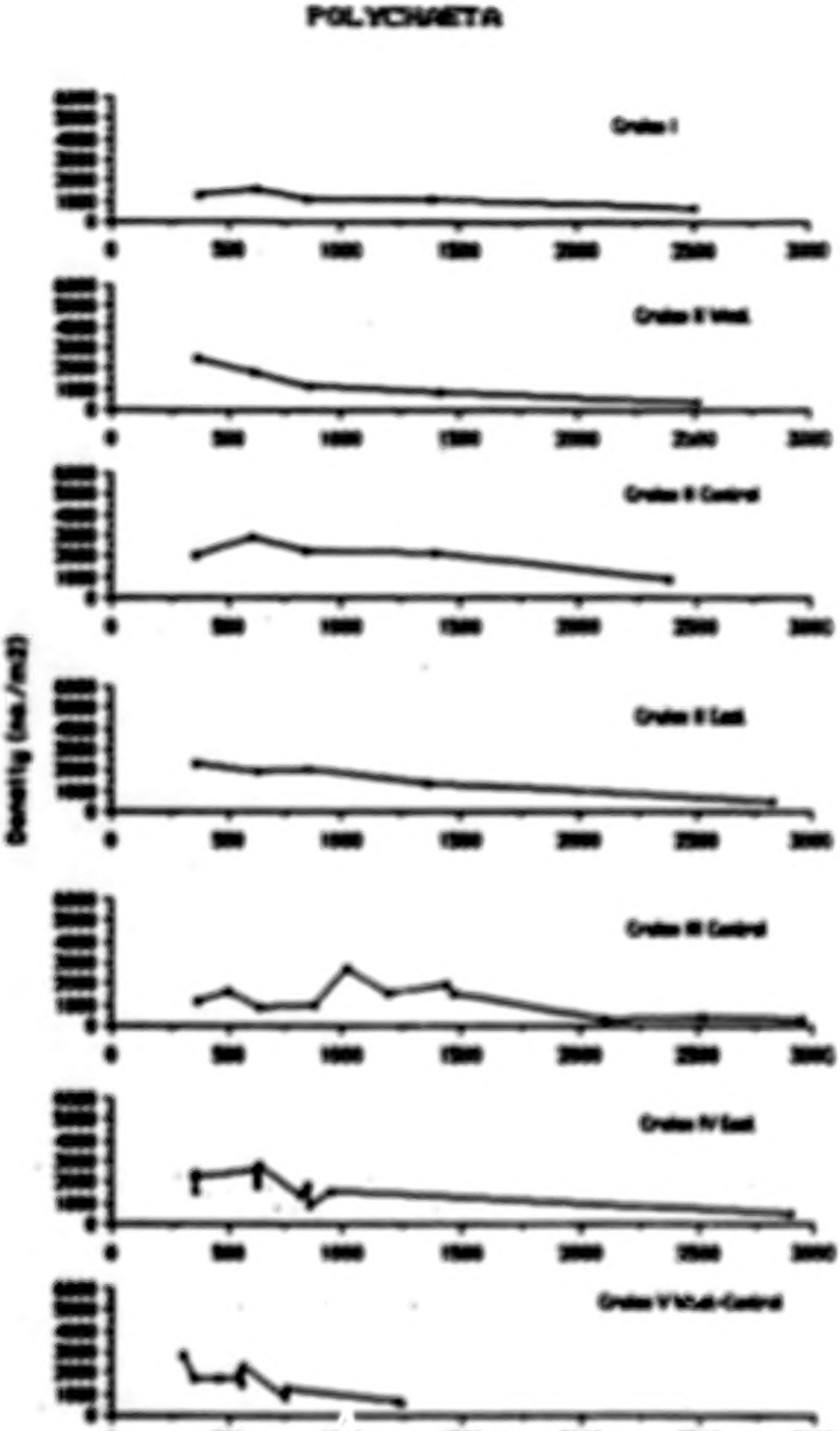

Figure 4-26. Polychaete densities (no/m^2) at all stations, all transects, and all five cruises.

low densities were found (167-386/m^2). On all cruises polychaete densities were lowest at depths greater than 2300 m. (Usually no samples were taken between 1500 and 2300 m.) For each of the transects sampled on Cruises I-V, maximum densities were observed at 613, 359, 354, 597, 1021, 630 and 298 m (Fig. 4-26). Excluding the deepest stations which always had the lowest densities the following depths on each transect sampled had the minimum density estimates: 1381, 1410, 354, 1355, 633, 819, and 1236 m (Fig. 4-26). From these data, polychaete densities usually reached their maximum at 300-630 m depths then decreased with increased depth.

Mean polychaete densities arranged by depth for all stations sampled on all transects show the following pattern of decreasing polychaete densities with depth:

Depth Range (m)	Density (No./m^2)
298- 492	1982
500- 900	1787
1500-2000	1441
2000-2845	482

Once more, densities were appreciably lower at depths greater than 2000 m than at shallower depths.

The effects of geographic variation within the Gulf were tested during Cruise II when five stations along each of three transects located in the western, central and eastern Gulf were occupied. Depths sampled were 354-359, 597-627, 838-854, 1355-1410, and 2386-2827 m (Fig. 4-26). Except for the shallowest depth range sampled, the maximum densities were observed along the Central Transect, while minimum values were found along the Western Transect. These extremes were reversed for the shallowest depth sampled. Polychaete densities on the Eastern Transect were intermediate.

On Cruises IV and V some similar depth ranges were sampled in the eastern Gulf and west-central Gulf. Mean densities by depth range are shown below.

Depth Range	Mean Density (No./m^2)	
	West-Central	Eastern
298-353 m	2269	2131
547-630 m	1876	2343
748-860 m	1069	1709

These results indicate polychaete densities may be higher in the eastern than west-central Gulf at depths in the two ranges of 547-630 m and 748-860 m, but not shallower, in the range of 298-353 m. These results are similar to the ones discussed for Cruise II which showed that western stations had lower densities than either central or eastern stations, except for the shallow depth 359 m which had the maximum density in this depth range contour.

Density comparisons among cruises can be compared using Central Transect stations C1-C5, that were each sampled three times (Cruises I-III). Densities (no/m^2) by station (depth) for each cruise are shown below:

Station	(Depth m)	Cruise		
		I (Nov)	II (Mar)	III (Nov)
C1	(354-365)	1242	2049	1177
C2	(597-633)	1523	2905	899
C3	(838-881)	1108	2263	989
C4	(1381-1465)	1085	2150	1564
C5	(2386-2518)	639	872	386

The highest densities were observed on Cruise II while the lowest densities were on Cruise III (except for Station C4).

Four stations in the eastern Gulf were occupied in consecutive years during the same "season" (May-June). Polychaete densities found on Cruises II and IV are shown below:

Station	(Depth m)	Density (No./m^2) Cruise II (1984)	Density (No./m^2) Cruise IV (1985)
E1	(353-354)	2333	2239
E2	(619-627)	1927	2601
E3	(819-846)	2051	1381
E5	(2827-2901)	473	515

These data show considerable variability between years as well as between "seasons" or cruises with few patterns or trends relative to increases or declines in polychaete density.

Polychaete Feeding Types

Polychaetes were classified according to feeding type on the basis of taxonomic family (Attachment A2.4). The total abundance and number of taxa within each feeding type was computed. A summary of this tabulation is shown in Figure 4-27. Deposit feeders (selective [SDF] and non-selective [NSDF]) were the most abundant polychaetes in terms of total counts and number of taxa. More families (16 with 99 total taxa) of carnivores (C) were collected than any other single category although the abundance of this group was less than either deposit feeders (NSDF and SDF) or omnivores (O). Suspension feeders (SF) and scavenger (S) were rarely found; the two categories combined representing only 8% of the polychaetes collected and identified. Non-selective deposit feeders were the most diverse group with 196 taxa in this category, while only 37 taxa were classified as scavengers.

Polychaete Depth Ranges

A total of 150 polychaete species were represented by 10 or more individuals (264 species occurred fewer than 10 times). The depth ranges of these 150 species (Attachment A2.5) showed an interesting pattern: the minimum depth of occurrence for 83% (124) of the species was in the range of 291-366 m and the deepest minimum depth of occurrence was only 639 m. The maximum depth of occurrence was more variable but indicated that depth

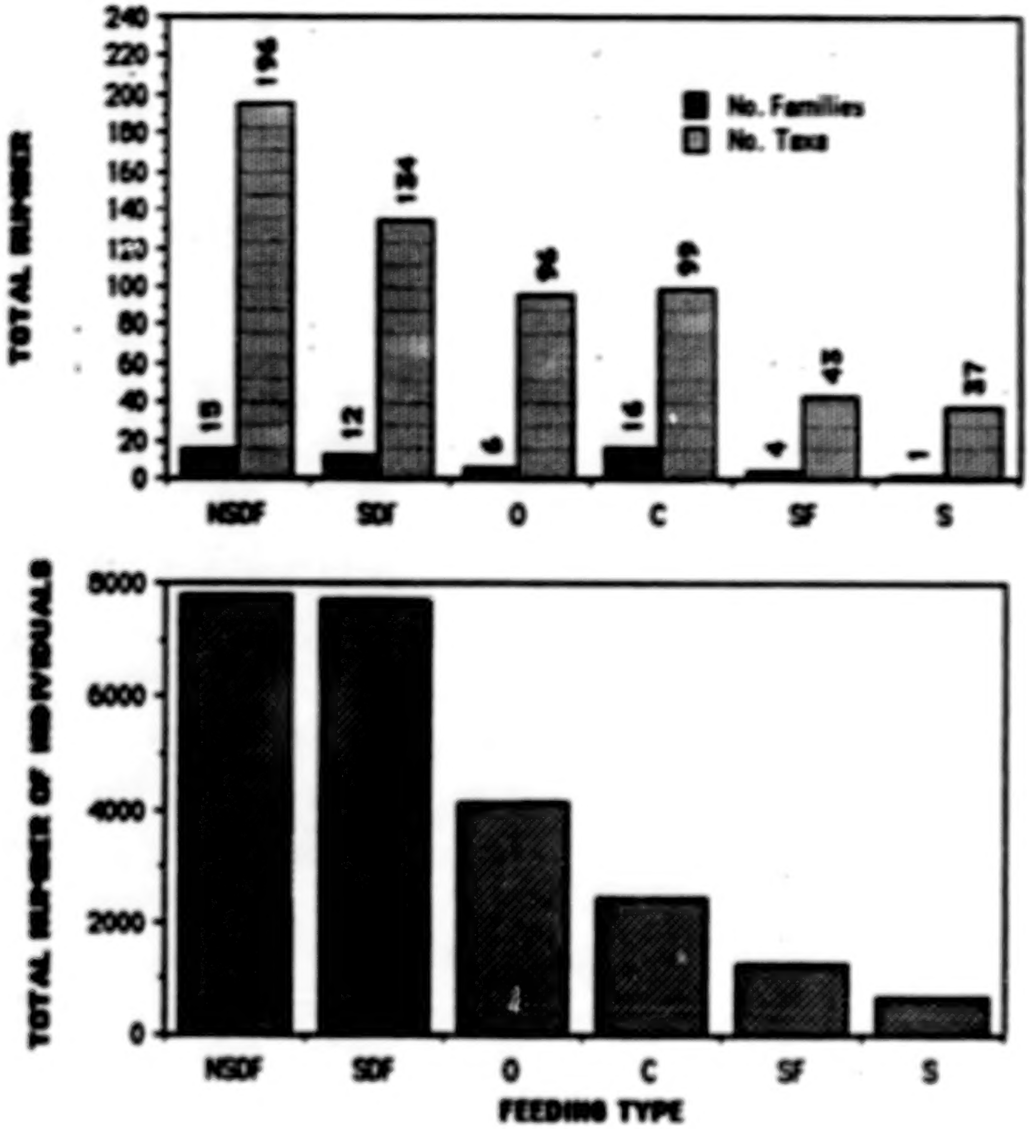

Figure 4-27. Polychaete feeding types showing number of families, taxa, and individuals in each feeding type. NSDF = non-selective deposit feeder; SDF = selective deposit feeder; O = omnivore; C = carnivore; SF = suspension feeder; S = scavenger.

per se was not limiting to many of the species. Forty-four of the 150 species were found to depths in the 2118-2959 m range. Only 27 species (18%) were restricted to less than 1000 m depths.

There were 50 species arbitrarily designated as abundant (i.e., ≥50 total individuals). Of these abundant polychaetes (Table 4-4), 64% were found from shallow (~300-350 m) to the deepest depths (>2000 m). Only two of these species were restricted to less than 1000 m depths, and the remaining 16 species had maximum depths of occurrence in the 1007-1507 m range (Table 4-4).

Polychaete Diversity

Polychaetes were the most diverse group of macroinfauna sampled. A total of 626 taxa, with 414 at the species level, were identified. Species identification was enabled by use of a diverse literature--e.g, we used some 43 references which are appended as Attachment A2.6. Most of the species were uncommon occurrences with low abundances and restricted distribution. Only 150 of the 414 species had a total count of 10 or greater individuals out of the total of 24,313 polychaetes counted. Further, only 156 of the 626 total taxa were observed in 10 or more of the 59 station collections.

Polychaete diversity as described by the mean number of species per replicate in a station collection was variable with depth, geographic location and cruise (season and year of collection). A test of depth-related differences was conducted during Cruise III when 11 stations were located at various depths along a single transect in the central Gulf. The number of species at each station ranged from 18 to 82 (Fig. 4-28). The highest number of species were found from 357 to 1465 m (range = 48-82, mean = 48). With the exception of Station C7, a possible area of hydrocarbon seepage, (number species = 82) this range was relatively consistent at 48-63 (mean = 55). At the deeper stations (>2101-2951 m) the mean number of species per station was 20, less than half the number at the shallower stations. Station C7 appeared to be anomalous with respect to the high number of species observed there. On other cruises where fewer stations were sampled over approximately the same depth range,

Table 4-4. A list of the 50 most abundant polychaetes.

Species	DEPTH (m) **Min**	 **Max**	Number
PHOLOE "SP.C"	343	1007	417
PARAMPHINOME JEFFREYSII	291	2377	188
PARAMPHINOME SP. A	298	2540	130
PARALACYDONIA PARADOXA	302	1236	211
SIGAMBRA TENTACULATA	320	2953	60
SYNELMIS KLATTI	343	2540	51
LITOCORSA ANTENNATA	291	870	1209
PIONOSYLLIS "SP. H"	298	1032	161
PIONOSYLLIS "SP.B"	344	860	56
SYLLIS (EHLERSIA) CORNUTA	336	1198	74
EXOGONE SP.B	291	2524	104
EXOGONE "SP.A"	347	2959	467
CERATOCEPHALE OCULATA	335	2904	220
AGLAOPHAMUS CIRCINATA	349	2524	57
GLYCERA PAPILLOSA?	344	2959	78
SARSONUPHIS HARTMANAE	298	1507	276
LUMBRINERIS VERRILLI	302	1507	113
LUMBRINERIDES DAYI	298	2945	229
LEITOSCOLOPLOS SP.A	291	1389	196
ARICIDEA SUECICA	291	2959	421
ARICIDEA (ARICIDEA) FRAGILIS	302	2945	69
ARICIDEA LOPEZI LOPEZI	298	1444	88
ARICIDEA (ACMIRA) SIMPLEX	335	1222	61
CIRROPHORUS LYRA	340	2945	116
LEVINSENIA GRACILIS	291	2959	371
LEVINSENIA UNCINATA	335	2953	91
SABIDIUS CORNATUS	344	2540	62
PRIONOSPIO CIRRIFERA	291	2524	272
PRIONOSPIO EHLERSI	320	1506	380
SPIOPHANES BOMBYX	298	2904	118
SPIOPHANES BERKELEYORUM	291	2902	505
AUROSPIO DIBRANCHIATA	298	2853	1190
THARYX ANNULOSUS?	298	2904	191
THARYX MARIONI	291	2959	231
DIPLOCIRRUS CAPENSIS	302	2377	168
DIPLOCIRRUS "SP.A"	291	2900	116
FAUVELIOPSIS SP.B	291	2959	283
OPHELINA SP.A	320	1507	70
TACHYTRYPANE JEFFREYSII	444	2904	50
TACHYTRYPANE SP.A	291	2540	571
KESUN SP. A	335	2897	88
NOTOMASTUS LATERICEUS	291	2959	52
NOTOMASTUS AMERICANUS	291	1440	59
BARANTOLLA "SP. A"	335	2540	86
MALDANE "SP.A"	302	1507	402
MYRIOCHELE HEERI?	320	1507	61
AMPHARETE "SP.A"	291	2118	75
TEREBELLIDES STROEMI	291	2533	173
TEREBELLIDES ATLANTIS	336	1507	153
EUCHONE INCOLOR?	298	1433	101

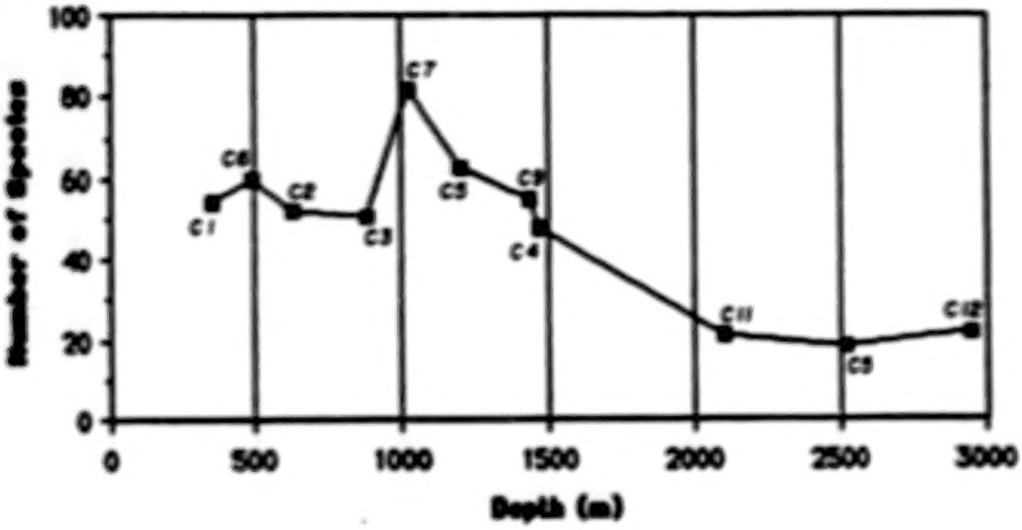

Figure 4-28. Numbers of polychaete species at each station (depth) along the Central Transect (Cruise III).

"deep" stations (2386-2901m) consistently had fewer species (mean = 27) than shallower stations ($\leq$1410 m) where the mean number of species was 62.

Abundant Polychaete Species

Polychaete species which had a total count of at least 50 were considered to be "abundant" and therefore potentially more important to understanding the deep-sea processes relating to polychaetes. The species listed above in Table 4-4 were selected (along with a few related species) for annotations relative to geographic distribution, depth range preferences, and feeding type. The results of this effort are shown in the annotated species list (Attachment A2.7) and maps (Attachment A2.8) showing collection location during this study.

4.2.5.11 Oligochaeta

Oligochaetes ranked 20th in overall abundance of the macrofaunal groups and 19th in total number of taxa, with only nine taxa. Six of the taxa were identified to the species level. Most of these are new records of distribution in the Gulf of Mexico, and three of them are new species being described by Dr. Christer Erseus of the University of Goteborg in Sweden.

Highest station species diversity for oligochaetes, four taxa, occurred at two stations on the East Transect, E3B and E3D (860 and 849 m depth). Highest oligochaete transect diversities, five taxa, were present on the East Transect on both sampling efforts for that transect (Cruise II and Cruise IV); lowest, one taxon, was at the West Transect.

Population densities for oligochaetes ranged from 0-63/m^2. The high of 63/m^2 occurred at two stations, E2C (619 m) and E5 (2827 m). Oligochaetes reached higher densities on the East Transect than on any of the other transects. Mean densities of oligochaetes on the East Transect were 34/m^2 on Cruise II and 27/m^2 on Cruise IV. Lowest transect mean density, 1/m^2, was at the West Transect on Cruise II.

Oligochaete mean densities arranged by depths are as follows:

Depth Range (m)	Mean Density (No./m^2)
298- 492	11
500- 900	21
1000-1500	6
2000-2945	19

Their increase in density deeper than 2000 m is different from any of the other macrofaunal groups studied except the sponges and brachiopods. Most of the other groups in the macrofauna showed depths of highest density at shallower levels with a marked drop in density below 2000 m.

The two dominant species of oligochaetes were two species of *Bathydrilus*, *B.* n. sp. (35 individuals taken at 13 stations) and *B. longiatriatus* (12 individuals taken at nine stations). The top five oligochaete species are listed below in order of overall abundance:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Bathydrilus n. sp.	2.21	35	13	613-2945
Bathydrilus longiatriatus	0.76	12	9	624-2475
Tubificoides n. sp.	0.19	3	2	339- 344
Phallodrilus n. sp.	0.19	3	3	627- 860
Limnodriloides monothecus	0.19	3	1	346

4.2.5.12 Gastropoda

Gastropod mollusks ranked 18th in overall numerical abundance in the macrofauna and 8th in total number of taxa with 53. Eight of the taxa which were identified to the species level, 27 to the generic level, and 18 to family level or higher.

The relatively low number of identifications to the species level reflects the great number of immature or juvenile specimens of very tiny sizes that were not easily identifiable to more specific levels than family or genus.

Numbers of gastropod taxa at individual stations ranged from 0 to 8, with the highest number of taxa found at Station C1, Cruise I at 344 m depth. Gastropod transect diversities were greatest (22 taxa) at the West-Central Transect on Cruise V, followed closely by 21 taxa on the East Transect on Cruise IV. Lowest transect diversity for gastropods was only three taxa at the West Transect on Cruise II.

Gastropod population densities ranged from 0 to 70/m^2, with the highest density occurring at Station WC5, Cruise V at 298 m depth. Mean transect density for gastropods was highest (30/m^2) for the Central Transect on Cruise II in April 1984. Two transects tied for lowest mean gastropod density at 7/m^2: the West Transect on Cruise II and the Central Transect on Cruise III.

Gastropod mean densities arranged by depth are as follows:

Depth Range (m)	Mean Density (No./m^2)
298- 492	20
500- 900	20
1000-1500	15
2000-2945	7

This contrasts with the bivalves, whose overall densities are more than 10 times greater than the gastropods and whose densities at the 1000-1500 m depth is relatively much higher.

The top seven taxa of gastropods from all macrofaunal samples are listed in order of overall abundance:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Cima sp.	0.57	9	6	547-1430
Philene sp.	0.51	8	8	563-2506
Melanella sp.	0.38	6	5	354-2475
Corinnaeturris sp.	0.25	4	3	344- 853
Crenilabium sp.	0.25	4	2	344- 759
Turbonilla sp.	0.25	4	3	352- 622
Solariella sp.	0.25	4	4	298-856

4.2.5.13 Aplacophora

The aplacophora ranked 10th in overall abundance for the macrofaunal groups collected in this study. They were not identified to the species level.

Aplacophora densities ranged from 0-211/m^2, with the highest density occurring at Station C7, Cruise III (1021 m depth). Aplacophorans were absent from only three stations, all of which were deeper than 2000 m.

Aplacophoran mean transect densities were highest, 88/m^2, at the East Transect on Cruise IV and lowest, 34/m^2, at the West Transect.

Mean densities for aplacophorans by depth are as follows:

Depth Range (m)	Mean Density (No./m^2)
298- 492	73
500- 900	65
1000-1500	50
2000-2945	7

Markedly lower densities occurred at depths greater than 2000 m than at shallower depths.

4.2.5.14 Bivalvia

The bivalves ranked fifth in overall abundance and seventh in total number of taxa. Some 55 taxa were identified, 41 of which were identified to the species level and 10 to the generic level. Bivalves reached their greatest diversity (19 taxa) at Station E1B, Cruise IV (346 m). Lowest bivalve station diversity was four taxa at Station E5, Cruise II. Highest total transect diversity (42 taxa) occurred at the East Transect on Cruise IV. Lowest transect diversity was 24 taxa at the West Transect on Cruise II.

The top 10 bivalve species arranged in order of overall abundance are listed below:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Eulamellibranchia sp. F	20.17	319	34	298- 860
Vesicomya sp.	16.57	262	40	344-2389
Malletia sp. B	15.11	239	39	298-1381
Crenella sp. A	14.23	225	34	547-1465
Nucula sp. A	13.15	208	46	339-1465
Cuspidaria sp.	8.92	141	33	298-2945
Lucina sp.	7.15	113	23	298- 881
Limopsis sp.	6.77	107	29	298-1465
Eulamellibranchia sp. B	6.64	105	21	402-2945
Yoldiella sp. A	6.64	105	9	856-2389

Density

Bivalve population densities ranged from 68-484/m^2. The highest station densities of greater than 400/m^2 occurred at the East Transect on Cruise IV at depths between 400-484 m. Highest mean density by transect was 296/m^2 at the East Transect on Cruise IV. Lowest transect mean density for bivalves (157/m^2) occurred at the West Transect.

Bivalve mean densities arranged by depth over all stations, all cruises are as follows:

Depth Range (m)	Mean Density (No./m^2)
298- 492	271
500- 900	227
1000-1500	260
2000-2945	124

Markedly lower density occurred at stations in the 2000-3000 m depth range than at shallower depths.

4.2.5.15 Scaphopoda

Scaphopods ranked 16th in overall abundance in the macrofauna and 18th in number of taxa, with 10 taxa identified. Five were identified to the species level and two to the generic level. Scaphopods were identified from the first three cruises only, and their taxa are listed below in order of overall abundance in the macrofauna:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Episiphon sp.	1.01	16	7	613-2506
Dentalium perlongum	0.38	6	5	359-2475
Cadulus sp.	0.32	5	3	881-2475
Dentalium didymum	0.25	4	1	2475
Heteroschismoides callithrix	0.19	3	1	1381
Dentalium callithrix	0.19	3	2	1390-1430
Pulsellum pressum	0.06	1	1	1430

Three of the seven taxa listed above, *Dentalium prolongum*, *Cadulus* sp., and *Pulsellum pressum*, were also present in the trawl megafaunal samples as more mature and larger sized individuals.

On the first three cruises, highest scaphopod station diversity, six taxa, was observed at Station C4, Cruise I (1381 m). Highest transect diversity of eight taxa was the Central Transect on Cruise I; lowest transect diversity of three taxa was at the East Transect, Cruise II.

Scaphopod population densities have been calculated for all five cruises and ranged from 0-105/m^2 with the highest station density at Station E2, Cruise IV (353 m). Highest transect mean density of 36/m^2 was at the East Transect on Cruise IV; lowest mean transect density, 8/m^2 was at the East Transect on Cruise II.

Scaphopod mean densities arranged by depth are as follows:

Depth Range (m)	Mean Density (No./m²)
298- 492	36
500- 900	20
1000-1500	21
2000-2945	17

Highest density was observed at the shallowest depth range.

4.2.5.16 Acarina

The marine mites of the family Halacaridae ranked 24th in order of total abundance in the macrofaunal samples taken by this study. They were not identified to lower levels.

Halacarid densities ranged from 0-46/m^2 with the highest station density occurring at Station WC5, Cruise V (298 m). Highest mean transect density for halacarids, 7/m^2 was at the West-Central Transect on Cruise V. No halacarids were found on the entire Central Transect on Cruise I nor on the West Transect on Cruise II.

Mean depth-specific densities follow:

Depth Range (m)	Mean Density (No./m²)
298- 492	5
500- 900	4
1000-1500	4
2000-2945	3

4.2.5.17 Ostracoda

Ostracoda ranked third in overall abundance and eleventh in species diversity, with 22 taxa--18 of which were identified to the species level. Only the myodocopan ostracodes were identified to the species level. The podocopans and other non-myodocopan ostracodes were not identified to more specific levels.

The maximum number of species of Ostracoda at any boxcore station (eight) occurred at five stations, viz., C2 (Cruise II), E3, E3C, and E3D (Cruise IV), and WC6 (Cruise V). These stations were all between approximately 550-850 m depth. Lowest number of species were seen at the deepest stations (greater than 2000 m). Highest overall transect diversity of ostracods, 17 taxa, was at the East Transect on Cruise IV; lowest, six taxa, was at the West Transect.

In general, highest population densities for ostracodes, i.e., greater than 500/m^2 occurred at depths of 550-850 m on all transects. Lowest densities of less than 100/m^2 occurred at the shallowest stations (<500 m) and at stations deeper than 2000 m. Mean ostracod densities by depth follow:

Depth Range (m)	Density (No./m^2)
298- 492	131
500- 900	446
1000-1500	273
2000-2945	135

The seven most abundant species of Ostracoda are listed in order of decreasing overall abundance below:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Euphilomedes sp. A	20.99	232	23	453- 860
Angulorostrum sp. A	17.64	279	44	298-1465
Philomedes sp. A	12.84	203	19	346- 838
Pseudophilomedes sp. A	8.03	127	18	346- 849
Harbansus sp. A	6.20	98	18	353-1236
Igene sp. A	2.21	35	11	563-2518
Metavargula sp. A	1.71	27	9	622- 860

4.2.4.18 Copepoda

Copepods, primarily harpacticoids, ranked 4th in overall abundance of macrofaunal groups. No species identifications were scheduled for the copepods from this project.

Station densities ranged from 56-807/m^2 with the highest density found at Station C4, Cruise II (1390 m) in April 1984. Lowest copepod density of 56/m^2 was at Station C12, Cruise III (2945 m) in November 1984.

Highest transect mean density for copepods, 499/m^2 was at the Central Transect on Cruise II in April 1984, lowest of 168/m^2 was at the West Central Transect on Cruise V in June 1985 followed closely with 169/m^2 at the Central Transect on Cruise III in November 1984.

Mean densities of copepods by depth show the following patterns:

Depth Range (m)	Mean Density (No./m^2)
298- 492	154
500- 900	262
1000-1500	348
2000-2945	228

Copepods were one of the few macrofaunal groups, along with the isopods, that had their greatest mean densities in the 1000-1500 m depth range.

4.2.5.19 Cumacea

Cumaceans ranked 14th in overall abundance and fifth in total numbers of taxa with 86 taxa, 76 of which were identified to the species level and eight to the generic level. Cumaceans reached their greatest species diversity of 14 taxa at two stations, viz., Station C1, Cruise I (344 m) and Station E3C, Cruise IV (849 m). Highest transect diversity of 53 taxa was at the East Transect on Cruise IV. Lowest transect diversity for cumaceans, 10 taxa, occurred on the West Transect. The most abundant cumaceans were:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Procampylaspis acanthomma	2.09	33	16	344-1021
Cumella antipai	2.09	33	13	598-2901
Campylaspis spinosa	1.96	31	16	346-1381

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Cumella erecta	1.14	18	11	563-2827
Cumella compacta?	1.14	18	5	298-1192
Eudorella n. sp. C	1.01	16	8	344-1430
Cumella bishopi	0.95	15	9	547-1465
Epileucon tenuirostris	1.39	22	16	344-2389
Cumella davae	1.26	20	13	298-2389

Density

Cumacean population densities ranged from 0-130/m^2. The highest density of cumaceans occurred at Station WC5, Cruise V at 298 m depth, and the lowest (0) at the following three stations: C6 and C11, Cruise III (492 and 2101 m) and WC12, Cruise V (1236 m).

Highest mean transect density for cumaceans (48/m^2) occurred on the East Transect on Cruise IV in May 1985. Lowest transect density (20/m^2) was at the West Transect on Cruise II in April 1984.

Cumacean mean densities by depth were:

Depth Range (m)	Mean Density (No./m^2)
298- 492	36
500- 900	38
1000-1500	28
2000-2945	15

This pattern is similar to those of the amphipods and tanaidaceans, with highest densities between the 500-900 m depth range, dropping off slightly in the 1000-1500 depths and finally declining drastically in depths of greater than 2000 m. This is in contrast to the other major crustacean group, the isopods, which reached their highest densities at deeper levels; i.e., between 1000-1500 m.

4.2.5.20 Tanaidacea

Tanaidaceans ranked sixth in total abundance and second in diversity of species with 186 taxa, of which 168 were identified to species and 13 identified to the generic level. Tanaidaceans reached their greatest numbers of taxa (47) at Station E3C (Cruise IV, Eastern Transect) and the lowest, five taxa, at Station C1 (Cruise III, Central Transect). In general, number of species of tanaidaceans was greatest between 600 and 1000 m depth and lowest at the deepest (>2000 m) and shallowest (<500 m) depths of this study. Highest tanaidacean transect "diversity", 124 taxa, was at the East Transect on Cruise IV; lowest, 50 taxa, was at the West Transect.

The ten most abundant species of tanaidaceans were, in order of decreasing abundance:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Pseudotanais sp. 1	18.91	299	52	298-2945
Mesotanais sp. 1	11.45	181	34	339-1390
Leptognathia sp. 15	10.94	173	37	344-2901
Apseudidae A	9.74	154	19	359-1465
Tanaella sp. 1	7.52	119	34	298-2945
Leptognathiidae genus A	5.82	92	28	298-1465
Mesotanais sp. 2	5.56	88	26	547-1390
Apseudes sp. 1	5.50	87	2	550- 624
Leptognathia sp.	5.44	86	33	298-2389
Typhlotanais sp. 5	4.17	66	24	298-2901

Density

Densities of tanaidaceans ranged from 28/m^2 to 512/m^2. Lowest density occurred at Station C1, Cruise III (357 m) and the high of 512/m^2 occurred at Station C7, Cruise III (1021 m), both on the Central Transect. Highest average density by transect (325/m^2) occurred on the Eastern Transect on Cruise IV in May 1985. Lowest average density (134/m^2) was at the Central Transect on Cruise III in November 1984. In general, tanaidaceans reached their highest densities (>400/m^2) on the Eastern Transect in May 1985 (Cruise IV) at depths ranging between approximatly 620-850 m.

Tanaidacean mean densities by depth were:

Depth Range (m)	Mean Density (No./m^2)
298- 492	114
500- 900	330
1000-1500	201
2000-2945	63

Overall density (all replicates pooled and divided by the total area sampled) of tanaids was higher at stations located in the middle of the depth range (e.g. from 500 to 1500 m) for most transects than at either deeper or shallower stations. There appeared to be a pronounced decline in tanaid densities below 2,000 m. On the Central Transect, tanaids were most abundant at Stations C2, C3, C4, C7, C8, and C9 (from 598 m to 1,465 m (Figs. 4-46). On the Western Transect, tanaid densities on Cruise II were highest at Station W3 (depth 854 m). On the Eastern Transect, tanaids were most abundant on Cruise II at Station E3 (depth 846 m), and on Cruise IV at stations between the 500 m and 1000 m isobaths. There was no clear east-west difference seen in tanaid density on the West-Central Transect; high and low densities were each seen at both ends of the transect.

4.2.5.21 Isopoda

Isopods ranked eighth in overall abundance and third in diversity of species with 133 taxa, 119 (89%) of which were identified to species and eight of which were identified to the generic level. Most of the Isopoda from this study are new species, hence their identification designation of a species code number following the generic name. It is hoped that the isopods from this study can be worked up into a series of monographs on deep-sea isopods of the Gulf of Mexico by Dr. George Wilson of the Scripps Institution of Oceanography.

The ten most abundant species of isopods are listed in order of overall abundance were:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Gnathia sp. 201	9.42	149	9	344-1226
Ischnomesus sp. 208	8.92	141	28	453-1381
Prochelator sp. 202	7.46	118	5	344- 492
Prochelator sp. 408	6.13	87	21	346- 860
Macrostylus sp. 256	5.94	94	15	630-2945
Prochelator sp. 235	5.50	87	28	339-2518
Chelator sp. 237	4.68	74	27	339-2518
Prochelator sp. 209	4.43	70	19	492-2518
Macrostylus sp. 223	4.36	69	19	547-1381
Torbolia sp. 203	3.86	61	25	339-2901

Isopods achieved their highest number of species (34) at Station WC9, Cruise V (759 m) in June 1985. Lowest diversity of isopod species, two taxa, occurred at Station C1, Cruise III (357 m) in November 1984. In general, the highest isopod species diversities (greater than 20 taxa at a station) occurred at the Central and West Central Transects between 600 and 1300 m depth. Lowest diversities of less than 10 taxa at a station were found at depths greater than 2000 m and at the shallowest stations (less than 500 m depth).

Highest transect diversity, 87 taxa, occurred at the East Transect on Cruise IV; lowest, 35 taxa, was at the West Transect.

Isopod population densities ranged from 28-580/m^2. Highest density of 580/m^2 occurred at Station C1, Cruise I (344 m); lowest of 28/m^2 was at Station W5, Cruise II (2506 m).

Mean densities by transect were highest (245/m^2) at the Central Transect on Cruise II in April 1984 and lowest (93/m^2) at the Central Transect on Cruise III in November 1984.

Mean densities by depth showed the following patterns:

Depth Range (m)	Mean Density (No./m^2)
298- 492	117
500- 900	152
1000-1500	178
2000-2945	66

Isopods differ from the other crustacean groups of the macrofauna, i.e., the amphipods, cumaceans, ostracods, and tanaidaceans in having their greatest densities at the deeper depths of 1000-1500 m instead of at 500-900 m. However, a marked decrease in density was noted for the deepest depth range.

4.2.5.22 Amphipoda

The Amphipoda ranked ninth in overall abundance and sixth in total number of taxa with 79 taxa identified--50 of which were identified to species. Amphipods reached their greatest species diversity of 21 taxa at Station C1, Cruise I (344 m depth) in November 1983. Lowest diversities were 0 at two stations: E1 (354 m), Cruise II and C12 (2945 m), Cruise III. Highest transect diversity (45 taxa) was found at the East Transect on Cruise IV in May 1985. Lowest transect diversity was 11 taxa at the West Transect on Cruise II in April 1984.

The top ten species of amphipod species were, in order of decreasing abundance:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Harpiniinae	11.76	186	37	298-2518
Pardisynopia n. sp. 1	9.17	145	36	547-2901
Phoxocephalidae sp. 1	9.04	143	30	298-1465
Byblis n. sp. 1	3.10	49	16	298-1430
Melita sp. 2	2.72	43	18	298-2101
Metaphoxus n. sp.	2.02	32	13	598-1390

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Melita sp. 1	1.90	30	15	298-1192
Synopiidae sp. 7	1.14	18	13	346-1236
Melita sp. 5	1.01	16	3	298- 849
Synopiidae sp. 5	0.95	15	10	352-1465

Amphipod population densities ranged from 0 to 232/m^2, with the high occurring at Station C7, Cruise III at 1021 m depth in November 1984. Highest transect mean density was 101/m^2 at the West Central Transect, Cruise V in June 1985. Lowest transect density for amphipods was 28/m^2 at the West Transect on Cruise II in April 1984.

In general the highest amphipod station densities of greater than 150/m^2 occurred at stations located between depths of 500-900 m. Amphipod mean densities (all stations, all transects) arranged by depths are as follows:

Depth Range (m)	Mean Density (No./m^2)
298- 492	68
500- 900	102
1000-1500	78
2000-2945	12

Looking in more detail at the amphipod station densities we find that overall densities of amphipods were typically highest at stations shallower than 1000 m. On the Central Transect, amphipod density was highest at Station C1 (depth 344 m) on Cruise I and Stations C2 and C3 (depths 598 and 838 m, respectively) on Cruise II. On Cruise III, which included many more stations down-slope on the Central Transect, amphipod densities were highest at Station C7 (1021 m), and declined rapidly at stations deeper than C7.

On the Eastern Transect, amphipod overall densities showed a similar trend, with highest densities at Stations E2 and E3 (depth 627 and 846 m, respectively) on Cruise II; and at various stations between 624 m (E2A) and 819 (E3) on Cruise IV.

On the Western Transect, amphipod overall densities were highest at Stations W2 (604 m deep) and W3 (854 m), and decreased at stations seaward of the 1000 m contour as well as the one station (W1) inshore of Station W2.

On the West Central Transect, there was no obvious east-west trend in amphipod abundance; the stations deeper than 1000 m had relatively low densities compared to nearly all the shallower stations.

4.2.5.23 Decapoda

The decapod crustaceans comprised only a minor part of the macrofauna as compared with their great abundance and diversity in the megafauna from this project. Decapods ranked 29th in overall macrofaunal abundance out of the 44 macrofaunal groups encountered in this study, i.e., in the lower 1%. They ranked 16th in number of taxa, with a total of 13 taxa identified from macrofauna samples, 10 of which were identified to the species level. The most abundant decapod species from macrofauna samples were:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Bathyplax typhla	0.51	8	7	547- 622
Callianassia sp. A	0.19	3	3	298- 353
Callianassia marginata	0.13	2	2	352
Pontophilus gracilis	0.13	2	2	619- 622
Axiopsis (*Calocarides*) sp. A	0.13	2	2	453- 622

Some of these species, i.e., *Bathyplax typhla* and *Pontophilus gracilis*, represent younger stages of species that were common in the trawl megafauna samples. Others, such as the thalassinids (*Callianassa* and *Axiopsis*) are burrowers in the sediments and are present only in the macroinfaunal samples from this study.

Highest decapod species diversity was three taxa at Station E2E, Cruise IV (622 m). This was the same station where the decapods reached their greatest density of 11/m^2.

4.2.5.24 Pogonophora/Vestimentifera

Eleven specimens of Pogonophora were taken in macrofaunal samples. The specimens have been sent to specialists in Great Britain for further study. They were found only on the Central Transect (Cruise III), the East Transect (Cruise IV), and the West Central Transect (Cruise V).

Highest station density for pogonophorans was 18/m^2 at the Station C7 (1021 m). They were taken in macrofauna samples only between the depths of 622-1226 m.

4.2.5.25 Sipuncula

Sipunculan worms ranked 13th in overall abundance of the macrofaunal groups. They were identified from the first three cruises only, from which 37 taxa were identified, 31 of which to the species level. The 10 most abundant taxa of sipunculans are listed below in order of abundance:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Golfingia sp. B	1.01	16	7	354-2827
Golfingia sp. F	0.57	9	3	354- 604
Onchnesoma steenstrup II	0.51	8	2	354- 359
Golfingia sp. G	0.44	7	2	359- 604
Golfingia sp.	0.38	6	5	357-1410
Golfingia sp. J	0.38	6	4	633-1465
Golfingia sp. E	0.25	4	2	359- 604
Golfingia sp. K	0.19	3	1	1309
Golfingia sp. I	0.19	3	1	627
Phascolion sp. A	0.13	2	2	344- 613

On the first three cruises, the greatest diversity of sipunculans, seven taxa, was at Station W1 (359 m); greatest transect diversity, 14 taxa, was at the Central Transect on Cruise I.

Population densities, ranging from 0-182/m^2, were calculated for sipunculans over all five cruises. The highest station density (182/m^2)

occurred at Station E1, Cruise IV (353 m). The highest transect mean density was 81/m^2 on the East Transect on Cruise IV. The lowest, 8/m^2, was the mean density for the Central Transect on Cruise III.

Sipunculan mean densities by depth are as follows:

Depth Range (m)	Mean Density (No./m^2)
298- 492	78
500- 900	35
1000-1500	15
2000-2945	4

Sipunculans, along with the hydroids, scleractinians, and kinorhynchs showed highest densities at the shallowest depths, with densities declining over all depths.

4.2.5.26 Priapulida

Priapulids are small, worm-like, coelomate animals that live buried in sediments in shallow and deep water. Only a few species are known world-wide. A total of 33 specimens were taken from macrofaunal samples in this study, ranking them 27th in overall abundance. They were not scheduled for identification to more specific levels because of their relatively minor contribution to the total macrofauna.

Priapulid population densities ranged from 0-28/m^2 with the highest density at Station C5, Cruise II (2389 m). Highest overall transect mean density, 8/m^2, was at the Cental Transect on Cruise II. Lowest transect mean density for priapulids of <1/m^2 was at the West-Central Transect on Cruise V.

Mean densities for priapulids arranged by depth are as follows:

Depth Range (m)	Mean Density (No./m^2)
298- 492	2
500- 900	1
1000-1500	<1
2000-2945	7

The priapulids were one of the few macrofaunal groups, along with the sponges and brachiopods, that showed highest mean densities at depths greater than 2000 m. However, their numbers were few overall.

4.2.5.27 Bryozoa

The bryozoans ranked seventh in overall abundance and fourth in total number of taxa. A total of 99 taxa were identified, 82 of which were identified to species and 12 to the generic level.

Station species diversities of bryozoans ranged from 0-14 species. Highest diversity was at Station C4, Cruise II (1390 m) in April 1984. Bryozoans were absent from the two shallow stations on Cruise III, C1 and C6 (357 and 492 m depth) in November 1984. In general the higher station species diversities for bryozoans (greater than 10 taxa at a station) show no particular depth patterns. Highest transect diversity for bryozoans, 34 taxa, occurred at the Central Transect on Cruise II in April 1984. Lowest transect diversity of 11 taxa was also at the Central Transect, but on Cruise I in November 1983.

The top ten bryozoan species arranged in order of overall abundance are shown below:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Nolella monniotae	112.05	1772	27	298-2901
Euginoma crualieri	18.27	289	37	298-2506
Nolella sp.	17.26	273	22	353-2945
Setosellina elegantula	6.89	109	24	339-2101
Sphaerulobryozoon pedunculatum	5.19	82	25	298-1465
Euginoma n. sp.	4.24	67	10	547-2901
Heloidoma implicata	3.73	59	7	339- 860
Pachyzoon atlanticum	2.91	46	16	298-2901
Metrarabdotomorpha aenigmatistes	2.34	37	8	550-1465
Bathralazoon foresti	2.21	35	11	547-2901

Five of the 10 species showed very wide depth ranges from near the shallowest to near the deepest depths sampled. Two of the species were found only deeper than 500 m, two were found only at depths shallower than 1500 m, and one species was restricted to depths shallower than 900 m.

Bryozoans are colonial animals thereby making counts of individual specimens very difficult. In the macrofauna samples of this study, counts were made of bryozoan "pieces". However, in most cases, these were intact, small colonies and not broken pieces of larger colonies.

Bryozoan population densities ranged from 0-1168/m^2, with the highest density occurring at Station E2B, Cruise IV (627 m) in May 1985. In general, the higher station densities (greater than 500/m^2) showed no particular depth patterns; i.e., high densities were found at all depths between 298-2101 m. Bryozoan densities were consistently lower at depths greater than 2500 m, however.

Highest transect mean density for bryozoans, 412/m^2, was at the East Transect on Cruise IV in May 1985; lowest transect mean density of 50/m^2 was at the West Transect.

Bryozoan mean densities arranged by depths show the following patterns:

Depth Range (m)	Mean Density (No./m^2)
298- 492	213
500- 900	256
1000-1500	91
2000-2945	121

A closer look at individual station densities for bryozoans showed typically very high densities at a few stations on each transect--usually from 500 m to 1500 m--and relatively low densities elsewhere.

4.2.5.28 Brachiopoda

Brachiopods ranked 23rd in overall abundance in the macrofauna. Only two species of brachiopods occurred in the macrofaunal samples, one of which was a new species Argyrotheca.

Species	Overall Density (No./m²)	No. of Specimens	No. of Stations	Depth Range (m)
Cryptopora rectimarginata	4.93	78	16	354-2518
Argyrotheca n. sp.	0.06	1	1	2101

Brachiopod population densities ranged from 0-158/m² with the highest density at Station C11, Cruise III (2101 m). Highest transect mean density, 18/m², was at the Central Transect on Cruise III; lowest, <1/m², was at the East Transect on Cruise IV.

Mean densities by depth for brachiopods were:

Depth Range (m)	Mean Density (No./m²)
298- 492	1
500- 900	2
1000-1500	2
2000-2945	26

Brachiopods are one of the few groups, along with the Porifera and Priapulida, that have their highest densities at depths greater than 2000 m.

4.2.5.29 Ophiuroidea

Ophiuroids in the macrofauna ranked 12th in overall abundance. Ophiuroids were identified to lower taxonomic levels from Cruise I samples only. There were 16 taxa, 13 of which were identified to the species level, from Cruise I macrofauna. Because so many of the specimens were juvenile forms that could be identified to genus or species only with great effort and expenditure of time, the ophiuroid specialist, Dr. Gordon Hendler, concluded that it was impractical to continue the effort on the remaining samples. On Cruise I, the highest species diversity for ophiuroids, seven taxa, was at Station C4 (1381 m) and the lowest, three taxa, was at C5 (2475 m). The most common ophiuroid at the Cental Transect on Cruise I were *Ophiotholia* sp. (at 853 and 1381 m) and *Amphilepis* sp. (at 2475 m).

Ophiuroid population densities ranged from 0-133/m² with the highest station density found at W3 (854 m). Highest mean transect density, 52/m², was found at the East Transect on Cruise IV; lowest, 26/m², was at the Central Transect on Cruise III.

Ophiuroid mean densities by depth were:

Depth Range (m)	Mean Density (No./m²)
298- 492	40
500- 900	45
1000-1500	37
2000-2945	18

4.2.5.30 Echinoidea

The echinoids ranked 26th in overall abundance of macrofaunal groups. This puts them in the lowest 1%. They ranked 20th in number of taxa, with only six taxa identified, three of which were identified to the species level and one to the generic level as shown below:

Taxon	Overall Density (No./m²)	No. of Specimens	No. of Stations	Depth Range (m)
Aceste bellidifera	2.28	36	25	298-2945
Hemiaster expergitus	0.44	7	4	344-2485
Aceste sp.	0.19	3	3	352-1236
Schizaster orbignyanus	0.06	1	1	2475

The two most abundant taxa of echinoids showed no particular depth limitations in the macrofaunal samples, being present from near the shallowest to the deepest depths sampled. Comparing with the megafaunal echinoids taken by trawl, we find that no *Hemiaster expergitus* were taken in trawl samples and only limited numbers of *Aceste bellidifera* were taken by trawl on Cruise IV at the E2 stations (615-630 m depth). By contrast, the small specimens of this species occurred in the macrofauna samples on all transects and at all depth levels.

4.2.5.31 Holothuroidea

Holothuroids ranked 19th in overall abundance in the macrofauna and 17th in total number of taxa. A total of 13 taxa were identified, four to the species level, four to the generic level, and five to family or higher levels.

Greatest number of holothuroid taxa, four, occurred at three stations: E2B and E3D, Cruise IV (627 and 849 m) and WC11, Cruise V (1226 m). Highest transect diversity, eight taxa, occurred on the West-Central Transect on Cruise IV. No holothuroids were taken at the Central Transect on Cruise I.

Holothuroid densities ranged from 0-84/m^2 with the highest density (84/m^2) reached at Station E2D, Cruise IV at 630 m. Highest transect average density, 37/m^2, was at the East Transect on Cruise IV; lowest, 0/m^2, was at the Central Transect on Cruise I. Holothuroids occurred in considerably higher densities on the East Transect on both cruises to that transect (Cruises II and IV) compared to all the other transects.

Mean densities for holothuroids by depth were:

Depth Range (m)	Mean Density (All Transects)	Mean Density (East Transect Only)
298- 492	5	13
500- 900	27	48
1000-1500	11	21
2000-2945	5	7

The eight holothuroid taxa identified to genus or lower in macrofaunal samples are listed below:

Taxon	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Protankyra sp.	6.96	110	25	352-2518
Myriotrochus sp.	5.37	85	23	346-2901
Echinocucumis hispida	0.25	4	3	819-2101
Pseudostichopus sp.	0.25	4	2	1430-2101

Taxon	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Molpadia agassizi?	0.19	3	3	598-1390
Benthodytes sp.	0.06	1	1	1465
Molpadia sp.	0.06	1	1	849
Molpadia barbouri	0.06	1	1	1226

Whereas *Protankyra* sp. was the most abundant holothuroid in the macrofauna samples taken at nearly all depths sampled, it was taken only twice in trawl samples, both times at Station C5 on Cruise I and Cruise III (2400 and 2504 m depths). *Myriotrochus* sp., the second most abundant holothuroid in the macrofauna was not taken in trawl samples. Adults of this genus are in the macrofaunal size range and are a very common and diverse deep-sea genus (Robert J. Carney, pers. comm.). The remaining six taxa of macrofaunal holothuroids were also fairly well represented in trawl samples, the macrofaunal specimens most likely being juvenile forms. The most abundant megafaunal holothuroid, *Mesothuria lactea*, was not taken in macrofaunal samples.

4.2.5.32 Ascidiacea

Tunicates of the class Ascidiacea, ranked 21st out of the 44 macrofaunal groups in overall abundance in this study. They ranked 12th in total number of taxa with 18 taxa, 11 of which were identified to the species level and three to the genus level.

Ascidian diversities ranged from 0-5 taxa per station. The two stations showing the highest tunicate diversities were Station C9, Cruise III (1430 m) and E3C, Cruise IV (849 m). Mean transect diversities for tunicates ranged from two taxa at the Central and West Transects on Cruises I and II, respectively, to 10 taxa at the East Transect on Cruise IV.

Ascidean population densities ranged from 0 to 49/m^2, with the highest density at Station C4, Cruise II at 1390 m depth. The greatest mean transect density, 13/m^2, was at the Central Transect on Cruise II. The lowest mean transect density for ascidians was 5/m^2 at the West-

Central Transect on Cruise V. Ascideans were absent from 25 stations, most of which were located at the shallowest and the deepest depths. None were found at stations shallower than 550 m.

The species of ascideans from this study are listed in order of decreasing abundances as follows:

Species	Overall Density (No./m^2)	No. of Specimens	No. of Stations	Depth Range (m)
Dicarpa simplex	5.37	85	26	550-2101
Bathystyeloides n. sp.	0.57	9	7	846-1465
Minipera papillosa	0.32	5	3	759-1465
Hexacrobylus indicus	0.32	5	3	849-2901
Polycarpa pseudoalbatrossi	0.32	5	3	748- 759
Minnipera pedunculata	0.25	4	3	2518-2901
Synoicum draucum	0.25	4	3	622- 849

A new species of ascidean and many new distribution records are being described in a publication by Drs. Claude and Francoise Monniot, who note that the ascidean density on the northern Gulf of Mexico continental slope is the highest known for ascideans in the deep sea. They also report that the 10 previously described tunicate species all live in the South Atlantic Ocean and many in the basins bordering South America. It is concluded that the deep Gulf ascidean fauna is partly cosmopolitan and partly of a South Atlantic origin.

4.3 MEGAFAUNA

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4.3 MEGAFAUNA

4.3.1 INTRODUCTION

The megafauna discussions below are based upon the fish and invertebrate collections made by trawling. Complete listings of the catch data can be found in Volume III: Appendices, specifically Appendices C3-1 through C3-11. Life history information (e.g., length-weight) was taken for selected species, these raw data can also be found in Volume III, Appendices C4-1 through C4-26. The life history information along with food habit and distributional data were used to prepare species or life history accounts for selected megafaunal invertebrates and fishes. Collectively, these data help set the stage for the comprehensive synthesis of the final year.

Below we first discuss the megafauna in terms of overall community structure and diversity and then discuss each major group, particularly emphasizing comparisons to the TerEco baseline and bathymetric distributions.

4.3.2 COMMUNITY STRUCTURE AND DIVERSITY

In this section we describe the relative abundance patterns of fishes and invertebrates by transect and depth. Based upon previously defined lack of any definitive seasonal or annual patterns, these topics do not warrant special discussion.

4.3.2.1 Numerical Abundance by Transect

Megafaunal invertebrates, based upon data from the five cruises, were some four to five times more abundant than fishes on each transect in terms of average density:

	Number/ha		
TRANSECT:	Western	Central	Eastern
Fish	1222	620	1511
Invertebrates	5045	2621	7952
Combined	6267	3241	9465

The Central Transect was characterized by the lowest density of megafauna (3241/ha) which was some 50% lower than density observed on the Western Transect (6267/ha) and only about one-third of the density found for the Eastern Transect (9463/ha).

4.3.2.2 Numerical Abundance by Depth

The total and mean densities (number per hectare) of demersal fish and invertebrates are presented by depth intervals on the three major transects in Table 4-5. Note that there are six depth intervals beginning with 328-423 m and ending with 2100-2855 m on each of the three major transects. The number of stations within each depth interval are not the same in the three transects. For instance, in the case of the 328-423 m interval, there are three stations on the West and Central Transects and five on the East Transect. Hence in the case of fish on the West Transect the sum of the densities at the three stations was 476 with an average number of individuals of 159/ha. Three major points stand out very clearly: (1) the densities of the invertebrates are consistently the larger, (2) densities are highest on the Eastern Transect and lowest on the Central Transect as described above, and (3) the densities tend to drop at and below the 1550 m isobath. A similar pattern was found for many of the macrofaunal groups.

In Tables 4-6 and 4-7, we show the relative total densities of the two dominant megafaunal invertebrate groups and species within groups, respectively. The point to be made is that only one or two species dominate the overall relative abundance patterns. One should note that the data in Tables 4-6 and 4-7 have not been adjusted by number of trawl tows and are only for comparison to one another, not to Table 4-5.

Table 4-5. Densities (individuals per hectare) of megafaunal invertebrates and demersal and benthopelagic fishes at six depth intervals on three major transects. (Tot. = Catch adjusted by bottom trawl and trawl size; CPE = Density/trawl haul.)

Depths 328-423 m

	Western Transect				Central Transect				Eastern Transect				
	Fish		Inverts		Fish		Inverts		Fish		Inverts		Mean
Tot.	476		897		197		345		704		2030	=	775
CPE.	159	+	299	+	66	+	115	+	141	+	406	=	198

Depths 465-750 m

	Western Transect				Central Transect				Eastern Transect				
	Fish		Inverts		Fish		Inverts		Fish		Inverts		Mean
Tot.	469		1960		175		732		347		4368		1342
CPE.	67	+	280	+	58	+	244	+	50	+	624	=	221

Depths 751-1000 m

	Western Transect				Central Transect				Eastern Transect				
	Fish		Inverts		Fish		Inverts		Fish		Inverts		Mean
Tot.	142		605		171		900		239		819		479
CPE.	47	+	202	+	34	+	180	+	40	+	117	=	103

Depths 1050-1500 m

	Western Transect				Central Transect				Eastern Transect				
	Fish		Inverts		Fish		Inverts		Fish		Inverts		Mean
Tot.	135		1541		56		273		219		715		490
CPE.	45	+	514	+	19	+	68	+	109	+	357	=	185

Depths 1550-2050 m

	Western Transect				Central Transect				Eastern Transect				
	Fish		Inverts		Fish		Inverts		Fish		Inverts		Mean
Tot.	0		0		11		182		0		0		97
CPE.	0		0		4	+	61		0		0	=	11

Depths 2100-2855 m

	Western Transect				Central Transect				Eastern Transect				
	Fish		Inverts		Fish		Inverts		Fish		Inverts		Mean
Tot.	0		42		10		189		2		20		44
CPE.	0		21	+	3	+	63		0		0	=	15

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Table 4-6. Total densities of the most abundant megafaunal invertebrate groups for sampled depth intervals.

	Depth (m)					
	328-423	465-750	751-1000	1050-1500	1550-2050	2100-2855
Decapoda						
Penaeidea	318	8.5	8.0	12.5	0	4.15
Brachyura	64	195.5	12.5	6.0	18	1.5
Galatheidea	31.5	102	9	6.5	3	1.0
Caridea	32	202.5	80	293	11	2.5
Anomura	3	7	9	4	3	2.5
Echinodermata						
Asteroidea	5	22	24	9	64	34
Holothuroidea	3.5	6.5	15	6	1.5	26
Echinoidea	3.0	2.5	2.5	1.5	0	
Ophiuroidea	13.0	140.0	24.5	26	2.5	82
Crinoidea	0	2.5	2.5	2	0	1

Table 4-7. Densities of the most abundant species of decapods that account for the density data seen in Table 4-6.

Taxon	Ave: Range:	375 (328-423)	608 (465-750)	876 (751-1000)	1275 (1050-1500)	1800 (1550-2050)	2478 (2100-2855)
		Depths (m)					
PENAEIDEA (All spp.)		318	9	8	12	7	5
Penaeopsis serrata		261	2	0	0	0	0
CARIDEA (All spp.)		32	203	80	293	12	3
Nematocarcinus rotundus		0	90	39	188	1	0
Plesionika holthuisi		1	94	3	0	0	0
Glyphocrangon aculeata		0	0	8	25	2	1
BRACHYURA (All spp.)		64	196	13	6	18	2
Benthochascon schmitti		31	62	1	0	0	0
Bathyplax typhla		11	129	7	2	0	0
Geryon quinquedens		1	3	4	3	12	1
GALATHEIDEA (All spp.)		32	102	9	7	3	1
Munida longipes		17	0	0	0	0	0
Munida valida		0	94	2	1	0	0
Munidopsis sigsbei		0	1	5	1	1	1

4.3.2.3 Species Diversity by Region and Depth

Species diversity (H' and number of species) of megafaunal invertebrates and fishes, by region and depth, are presented in Figures 4-29 through 4-31, and 4-32 through 4-34, respectively. For invertebrates, there were no clear trends in the diversity index by depth nor were there any apparent substantive differences in invertebrate diversity among the three regions. Using 30 species as a reference point, 80% of the collections taken on the Central Transect had fewer than 30 invertebrate species whereas only about 30% of the collections on both the Eastern and Western Transects had fewer than 30 species (Figs. 4-29 through 4-31). At least part of this difference is attributable to more samples being taken at depths below 1250 m on the Central Transect than on either the Western or Eastern Transects. Depths below 1250 m appeared characterized by fewer species than shallower depths.

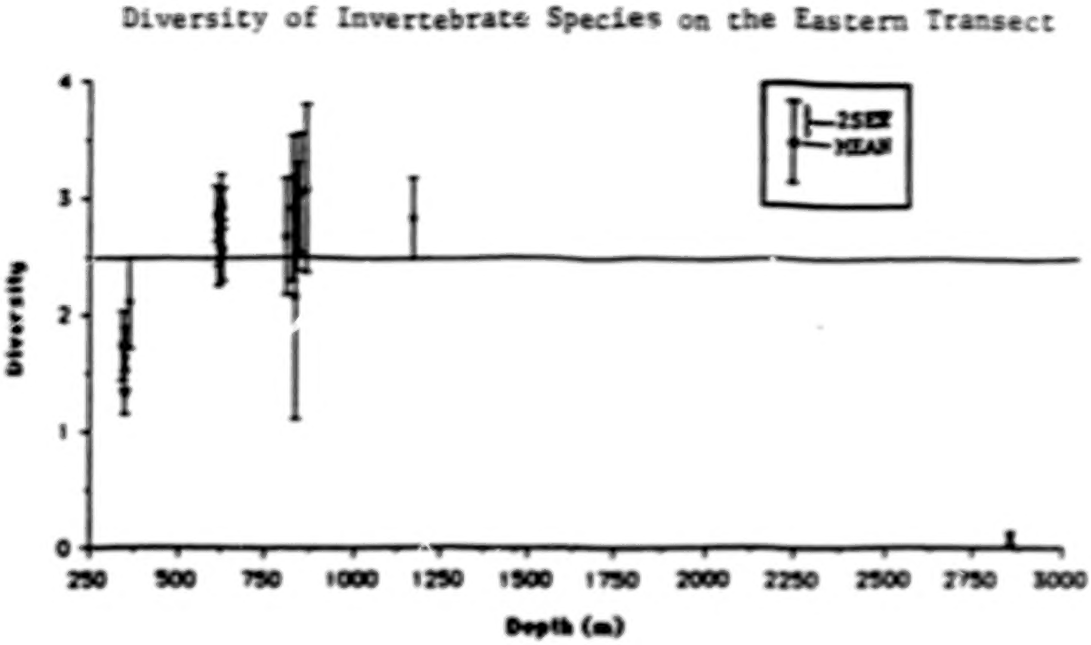
Examination of the fish diversity data suggests a decline in diversity as well as number of species at depths exceeding 1250 m (Figs. 4-32 through 4-34). There were no obvious differences in fish diversity among the three regions.

4.3.2.4 Bathymetric Zonation of Megafauna

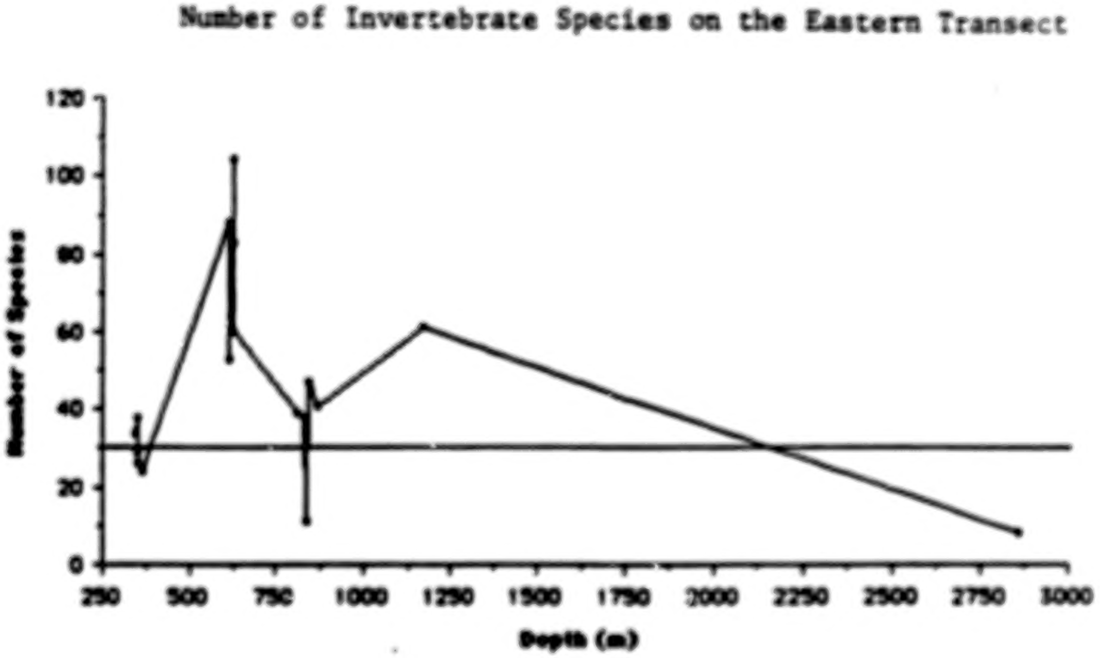
The results in the first two Annual Reports emphasized vertical zonation discussions drawing upon data from Cruises I through III. The preliminary conclusions were that a case could be made supporting the zonation scheme proposed in the TerEco baseline (Pequegnat 1983).

Cluster Analyses

The data derived from Cruises IV and V have provided support for a conception presented in earlier reports as to how faunal assemblages are distributed over the upper and middle portions of the continental slope. For the past several years, oceanographers have differed as to whether or not benthic animals are arrayed on the slope in discernible vertical bands or zones. Although there is general agreement that the composition of the faunal assemblages changes with changes in depth, there are those who

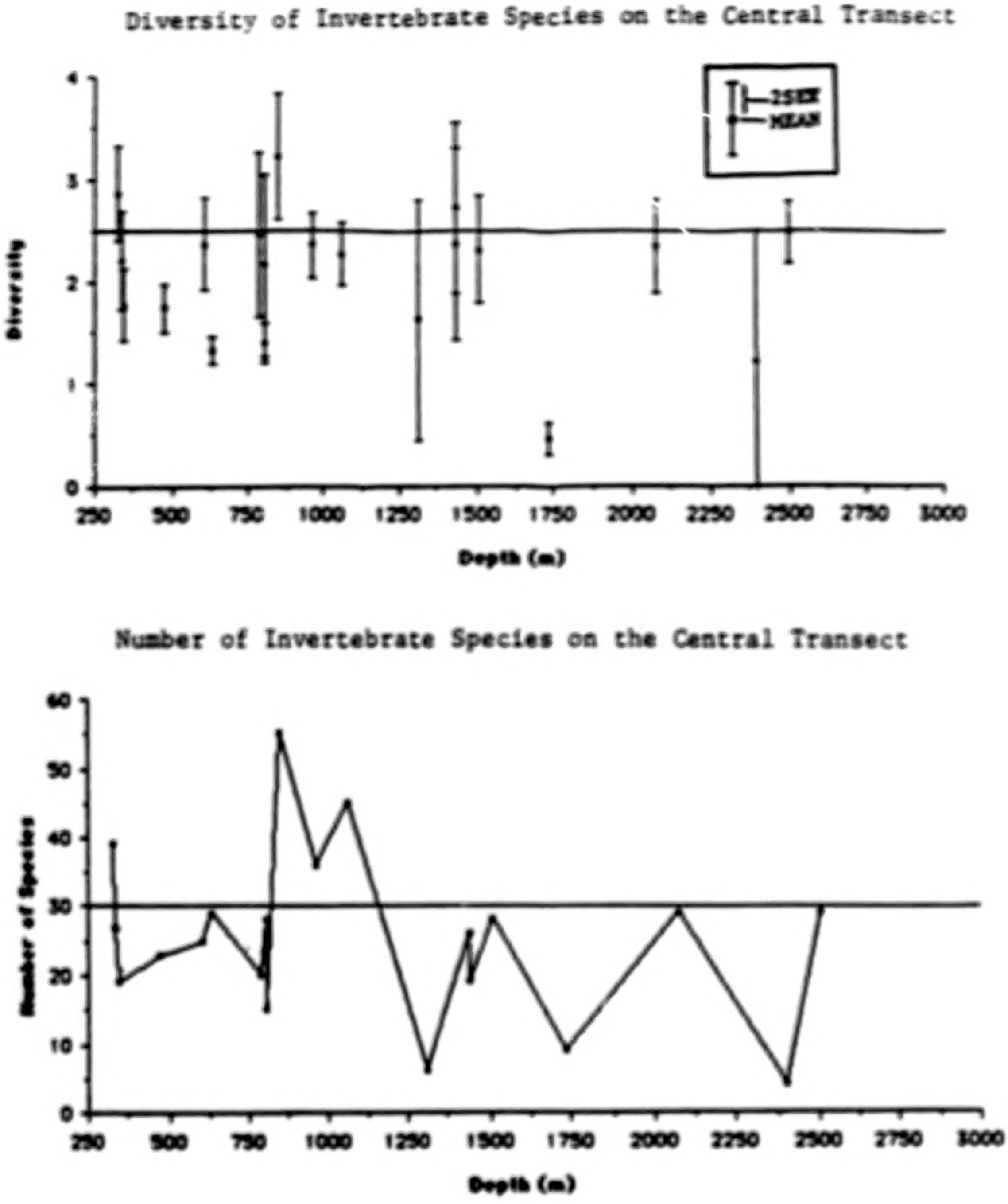


Diversity of Invertebrate Species on the Eastern Transect



Number of Invertebrate Species on the Eastern Transect

Figure 4- 29. Species diversity and number of species of megafauna invertebrates for the Eastern Transect, Cruises I-V.

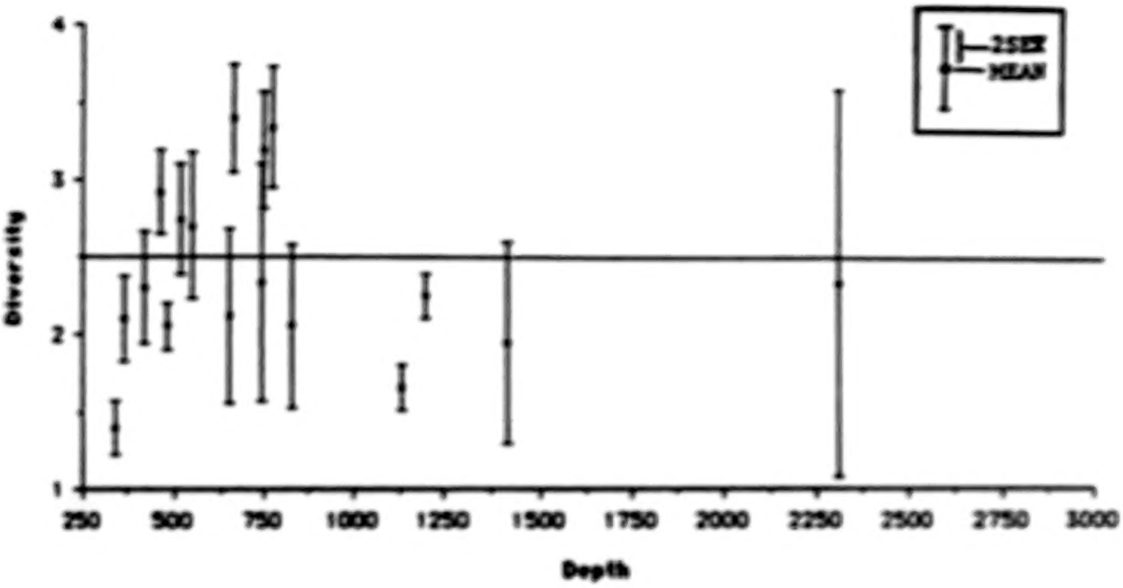


Diversity of Invertebrate Species on the Central Transect

Number of Invertebrate Species on the Central Transect

Figure 4-30. Species diversity and number of species of megafauna invertebrates for the Central Transect, Crusies I-V.

Diversity of Invertebrate Species on the Western Transect



Number of Invertebrate Species on the Western Transect

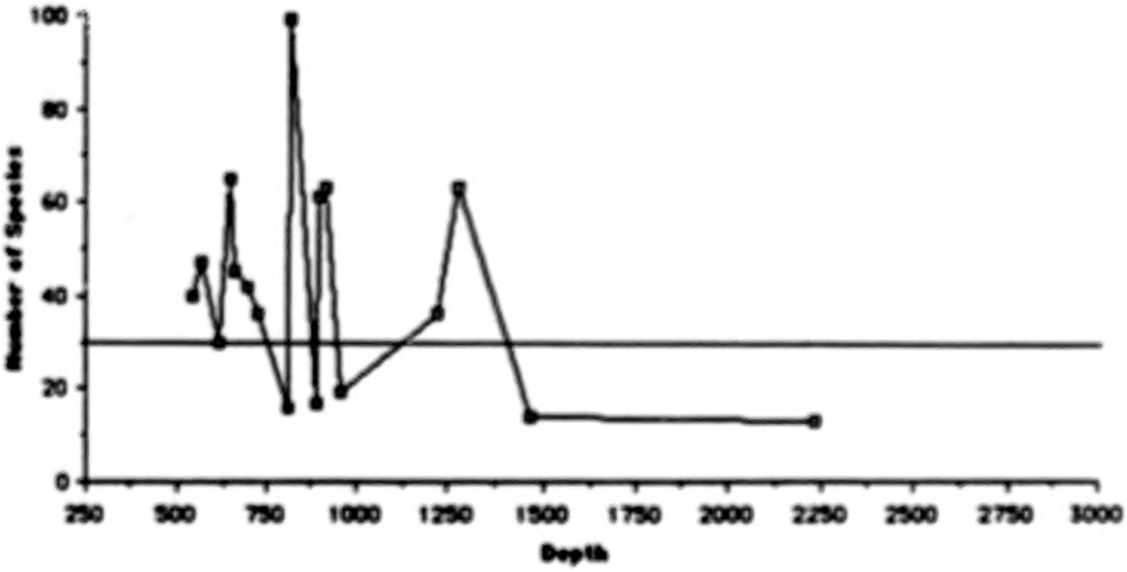
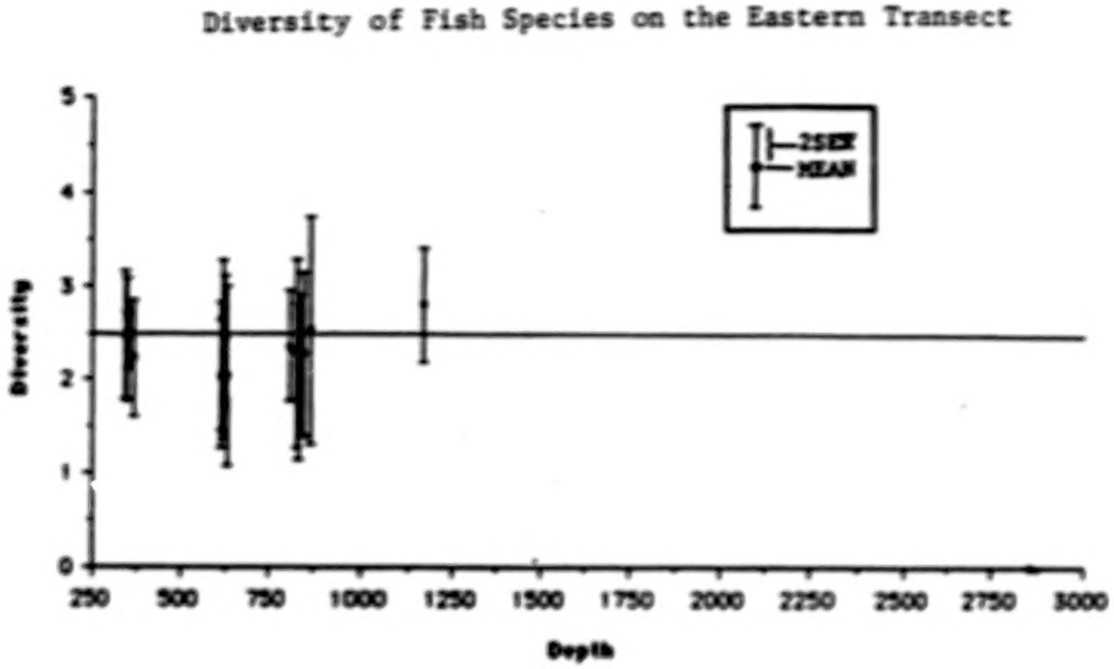


Figure 4-31. Species diversity and number of species of megafauna invertebrates for the Western Transect, Cruises I-V.



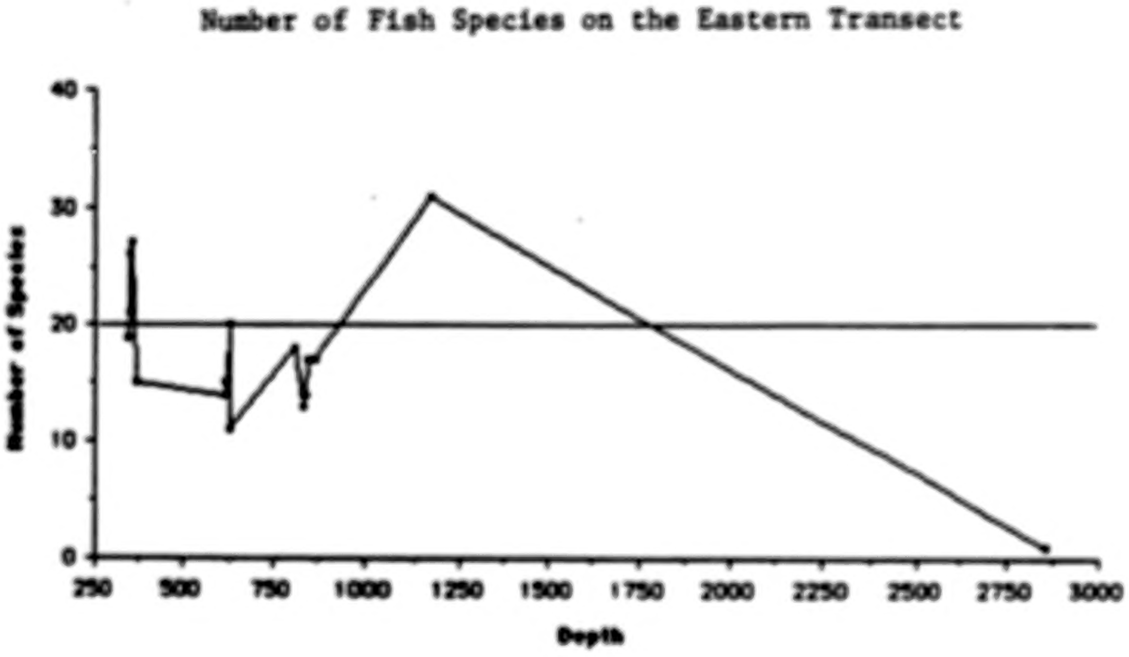
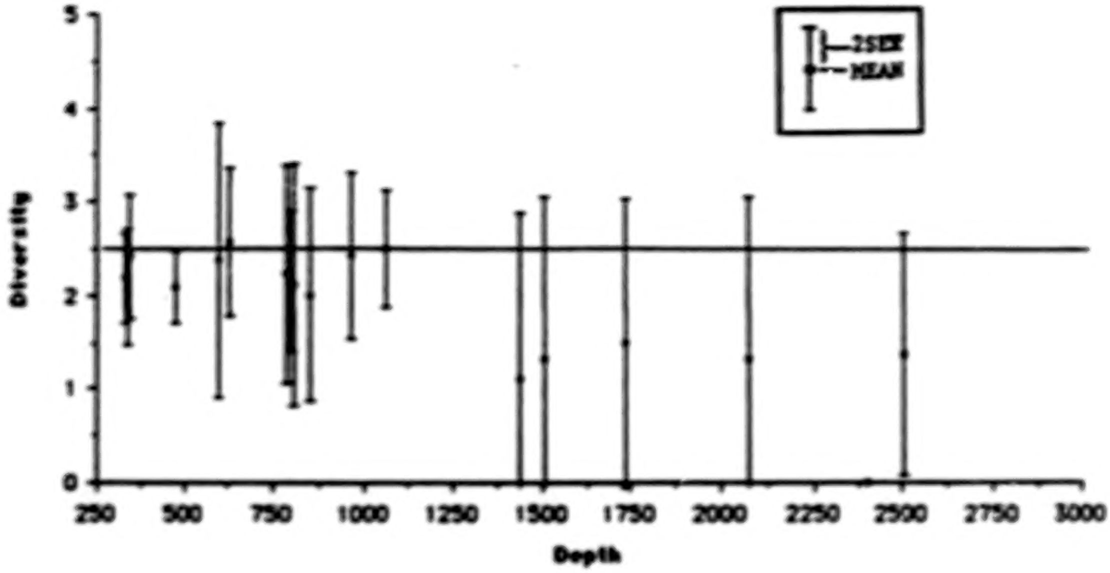


Figure 4-32. Species diversity and number of species of fishes for the Eastern Transect, Cruises I-V.

Diversity of Fish Species on the Central Transect



Number of Fish Species on the Central Transect

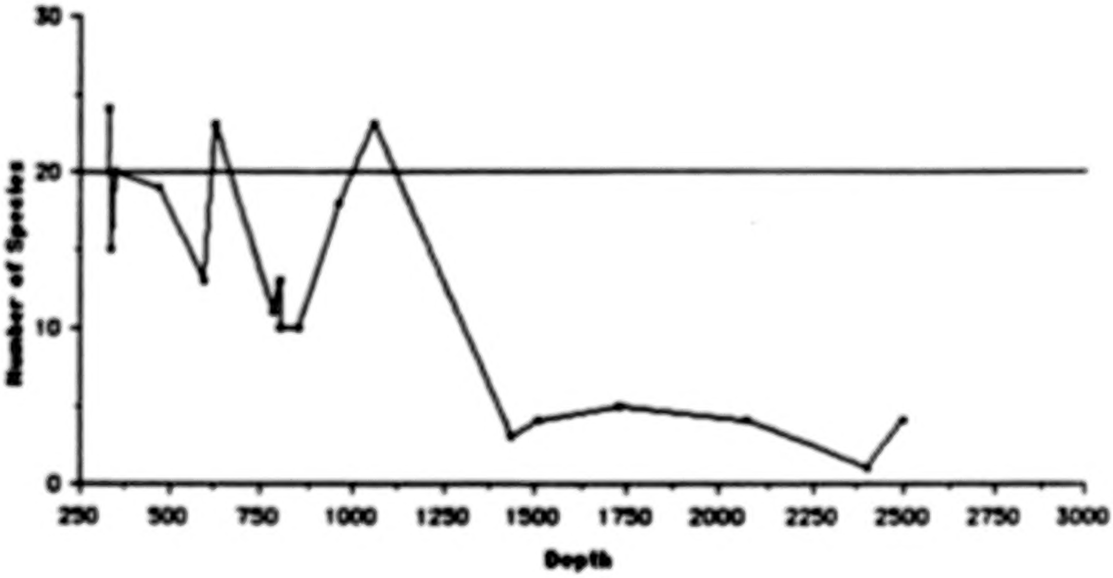
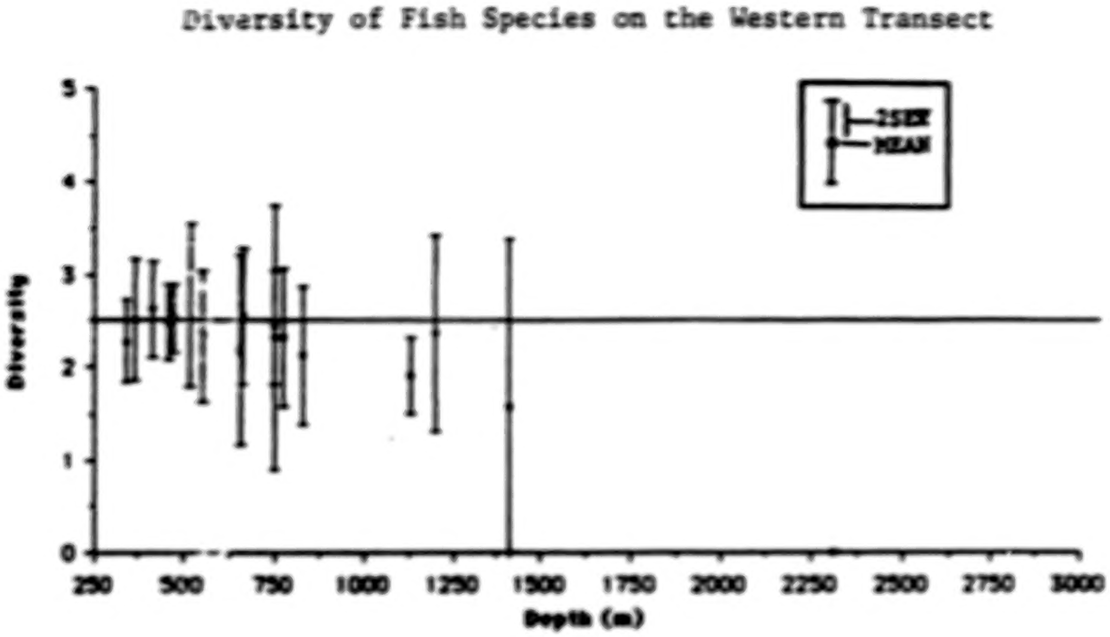


Figure 4-33. Species diversity and number of species of fishes for the Central Transect, Cruises I-V.



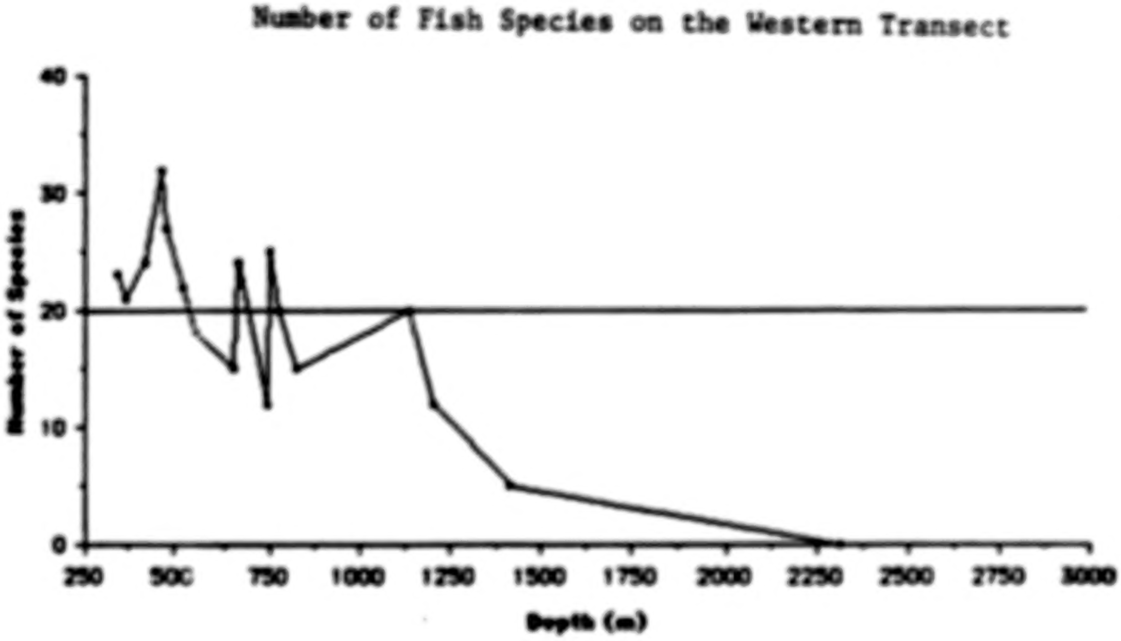


Figure 4-34. Species diversity and number of species of fishes for the Western Transect, Cruises I-V.

believe that the so-called zones are artifacts of sampling, i.e., that the limits of the zones are wholly related to the depths at which sampling was done. One must point out, however, that Haedrich et al. (1975, 1980) identified four faunal zones on the U.S. North Atlantic slope, and in 1983 Hecker et al. in an MMS report designated five faunal zones on the same slope. In the same year, Pequegnat (1983), again in an MMS report, identified five major zones on the slope and rise of the Gulf of Mexico. More recently the 1986 report on the MMS study of the U.S. North Atlantic benthic fauna carried out by Battelle, Lamont-Doherty, and Woods Hole contains descriptions of six faunal zones on the slope. These findings, which are based upon both classification and ordination analyses, reveal that the replacement of species with depth is not uniform. In other words the "rate of replacement" is not the same on all vertical aspects of the slope. Accordingly, one may regard zones as being large areas of relatively small faunal change with depth that are separated by smaller areas where the rate of exchange of species is high. These separations have been referred to as "breaks", but this is not a wholly acceptable term because it tends to ignore the fact that few or many taxa may be shared between neighboring zones.

It was reasoned that if this concept of zones is correct, then there should be far fewer exchanges of faunal species sampling along isobaths than sampling up or down the slope. And, by the same token, sampling along successively deeper isobaths should show increasing degrees of difference when compared with the samples from the shallowest isobath. Thus, it was decided to trawl isobathymetrically on consecutively deeper isobaths along two transects, namely, the East Transect during Cruise IV (Fig. 4-35) and the West-Central Transect during Cruise V, as shown in Figure 4-36. Note that Stations E1, 1a, 1b, and 1c are arrayed slightly above or below one isobath at a depth of about 350 m, whereas 2, 2a, etc., and 3, 3a, 3b, etc. are on isobaths having depths of about 625 and 840 m, respectively. Somewhat the same depth relationships were established on the West-Central Transect but the trawling tended to stray off the isobath to a greater degree than on the East Transect (Fig. 4-36). In particular note the large depth ranges at Stations WC6 and WC11.

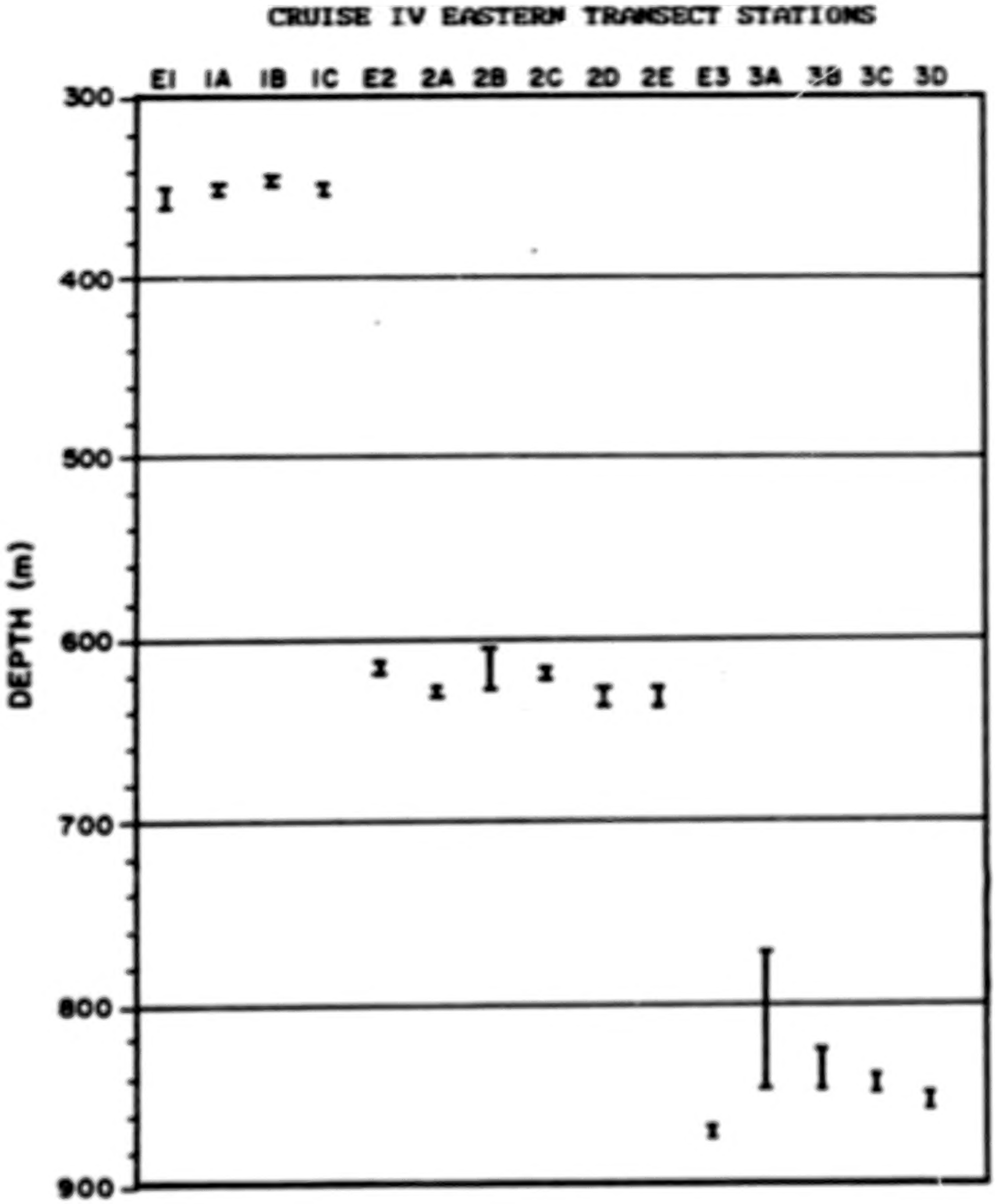


Figure 4-35. The range of depth (length of vertical lines) covered by trawling isobathymetrically as nearly as possible along three "horizontal transects" of increasing depth (E1 to E3) in the Eastern sampling area.

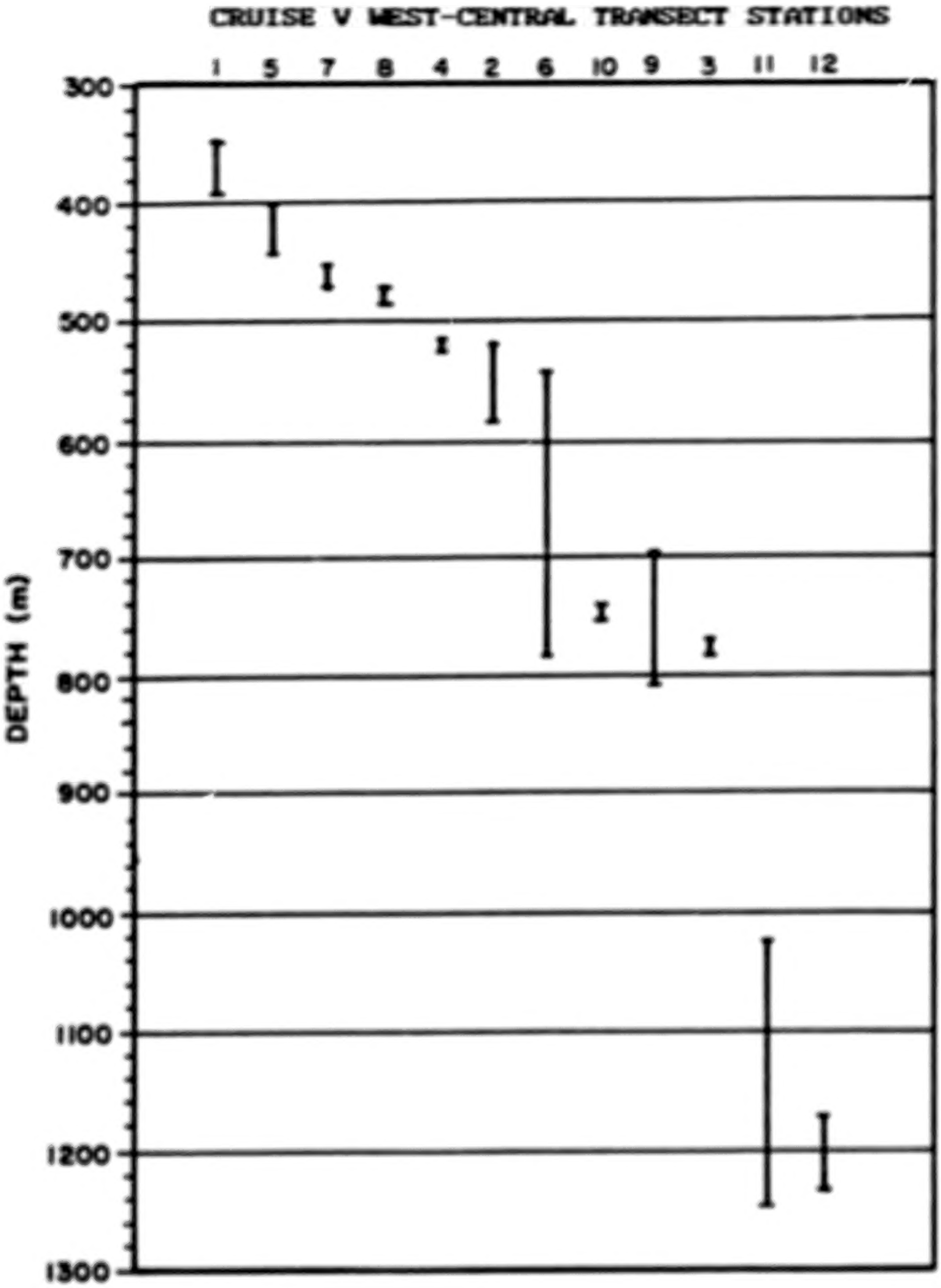


Figure 4-36. The range of depth covered at individual stations by trawling isobathymetrically as nearly as possible along three "horizontal transects" of increasing depth in the West-Central sampling area.

The Normalized Expected Species Shared (NESS) similarity measure (Grassle and Smith 1976) was used to analyze data derived from Cruises IV and V. Figure 4-37 shows the dendrogram that results from the application of NESS to all of the megafaunal invertebrates taken during Cruise IV. There is a clear separation of the faunal clusters from one isobath to another. Moreover, the E2 and E3 series of stations are more closely related to one another than to the E1 series. The separation of Station E2E from the others on the isobathresults from the fact that it lacked a few species and had others in reduced numbers as compared with other stations on the isobath. This gave it a pattern that resembled those more typical of the E3 depth series. Essentially the same major clusters occur when the fish data are analyzed (Fig. 4-38), but there are some differences in station pairings. Note, however, that in the E1 series of four stations that E1, 1B, and 1C are closely related and E1A is the outlier in both figures. In the E2 series Stations E2B, 2C, and 2D are clustered together with E2 as an outlier in both figures. The E3 series of five stations is much more tightly clustered for invertebrates than fishes and the pairings do differ except that Stations E3A and E3C are tightly clustered in both, although with different partners.

The dendrograms (NESS) for Cruise V invertebrates and fishes in the West-Central region, as shown in Figures 4-39 and 4-40, again show a tendency toward isobathic clustering with two major clusters, each of which is subdivided into two. Reference to Figure 2-1 (map of stations) and Figure 4-36 shows that the trawling was not carried out as effectively here as on Cruise IV. Stations are closely clustered where the range between the shallowest and deepest parts of the sampling was 70 m or less. In the case of WC6, the range was over 240 m. This depth difference will not always make much difference unless it crosses a zone of species flux. The clusters derived from the invertebrate and fish data are remarkably similar. Note, for example, that in both Figures 4-39 and 4-40 Stations WC1 and WC5 are paired and Stations WC2, 4, 7, and 8 form a cluster, as do WC3 and 9 and WC11 and 12, and in both WC10 is an outlier. It is only Station WC6 that shifts its position, clustering with the

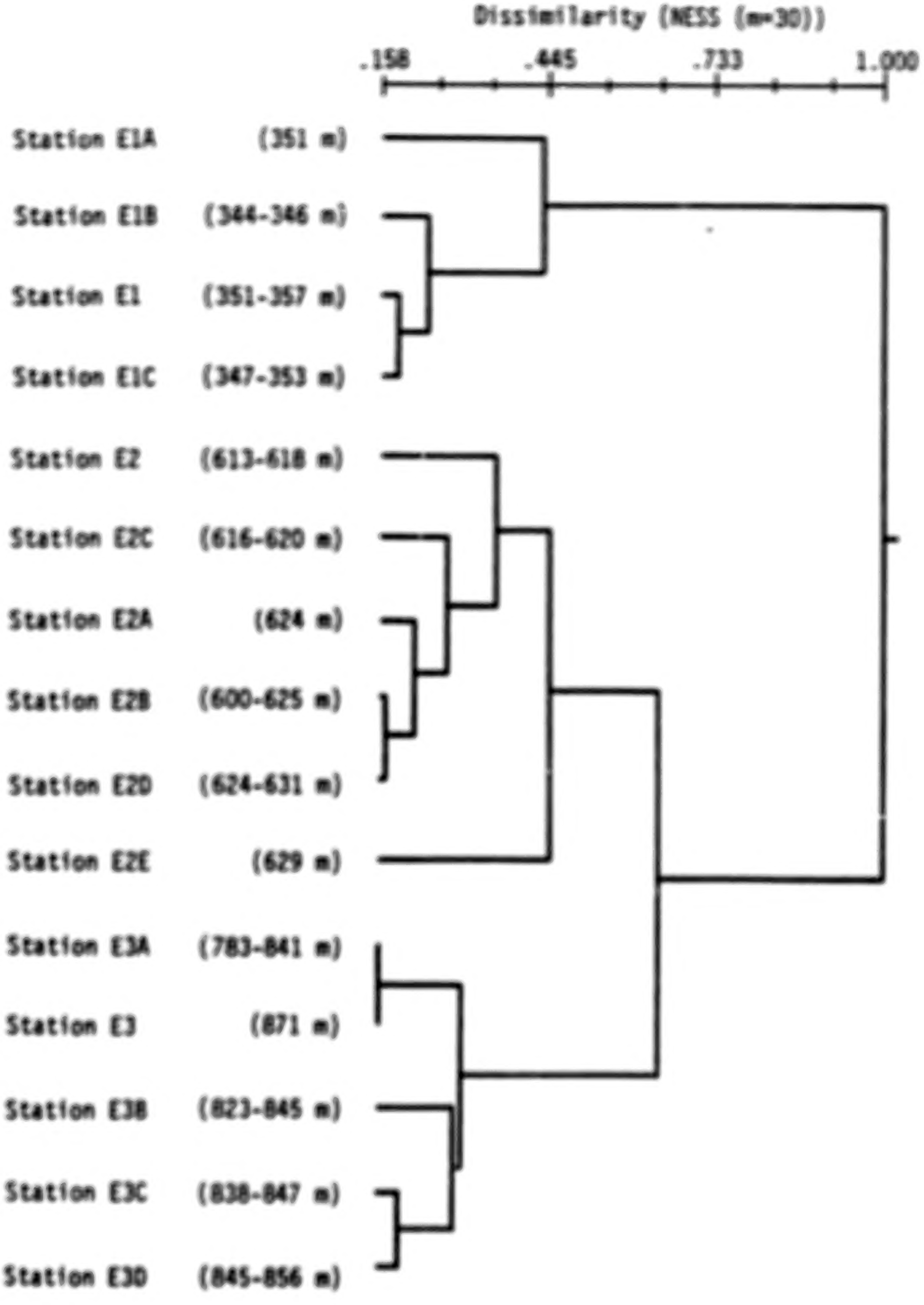


Figure 4-37. All invertebrates taken by trawl from the 15 stations of Cruise IV on the Eastern Transect clustered by NESS at 30 individuals. Similarity values between pairs of stations equal the reciprocal of the values given at the top of the figure. The major isobathic clusters are easily separated. Outlier stations such as E1A result less from depth than from sampling.

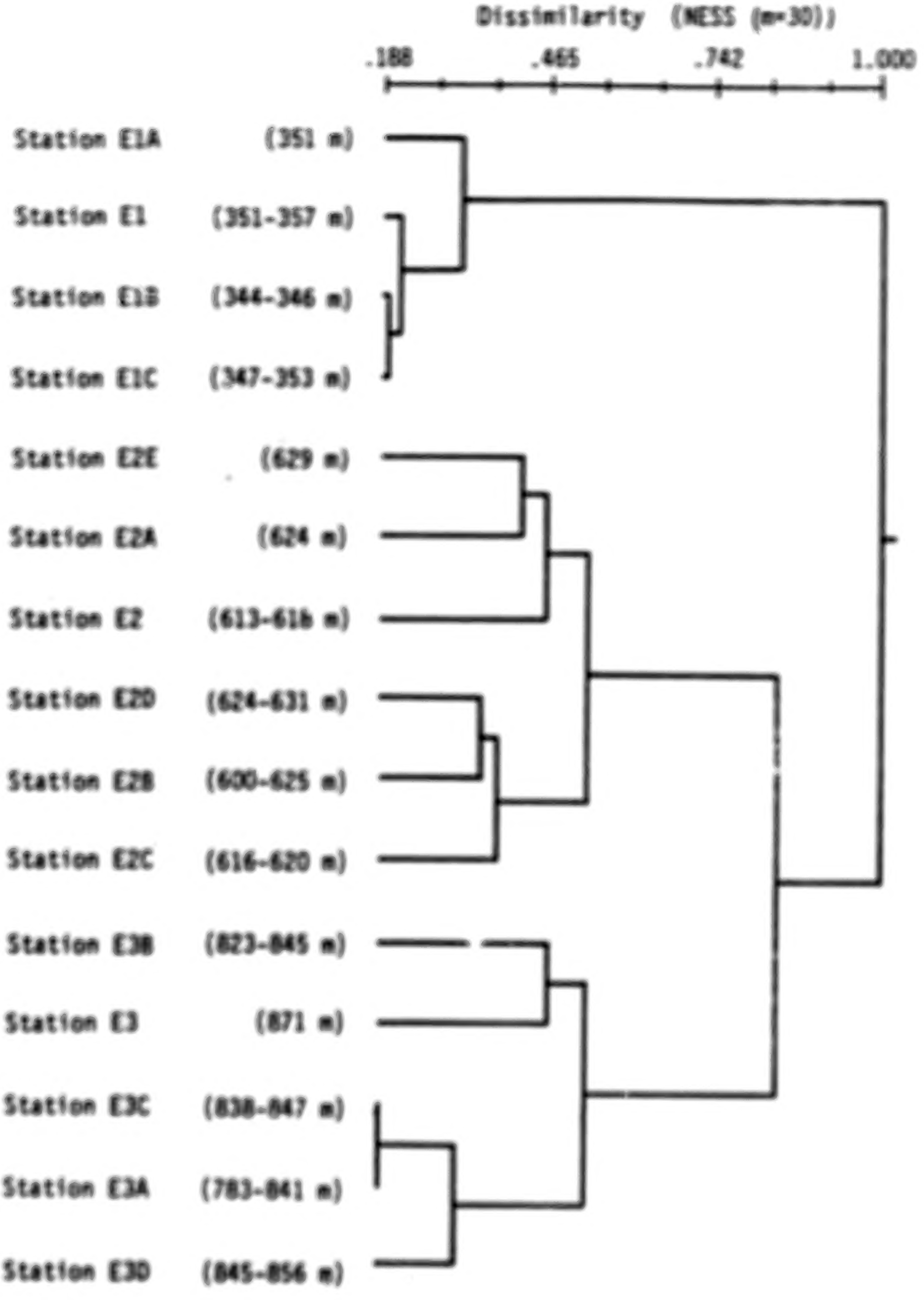


Figure 4-38. All fishes taken by trawl from the 15 stations of Cruise IV on the Eastern Transect clustered by NESS at 30 individuals. Comparison with invertebrate clusters in Figure 4-37 shows a high level of similarity.

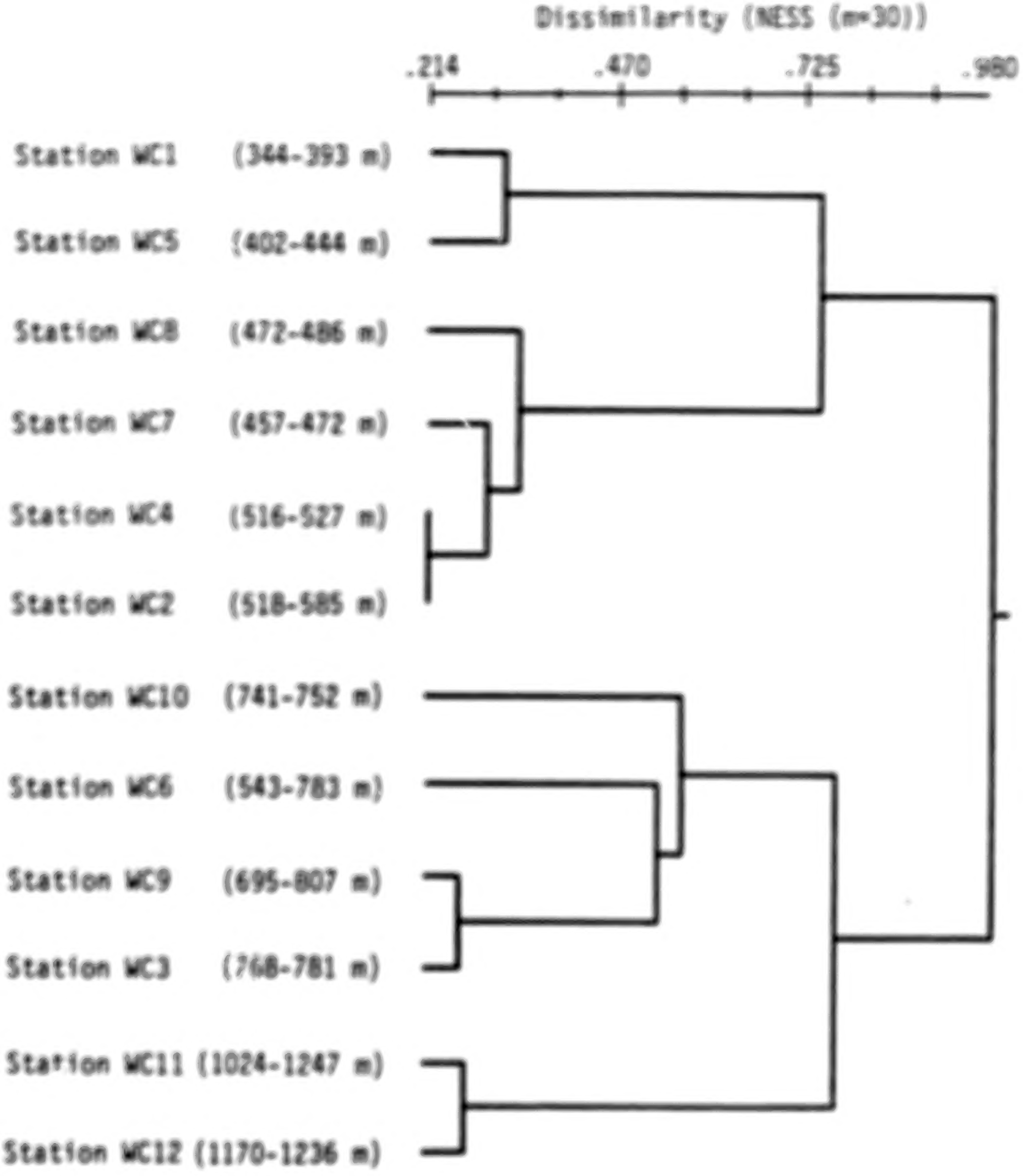


Figure 4-39. All invertebrates taken by trawl from the 12 stations of Cruise V clustered by NESS at 30 individuals.

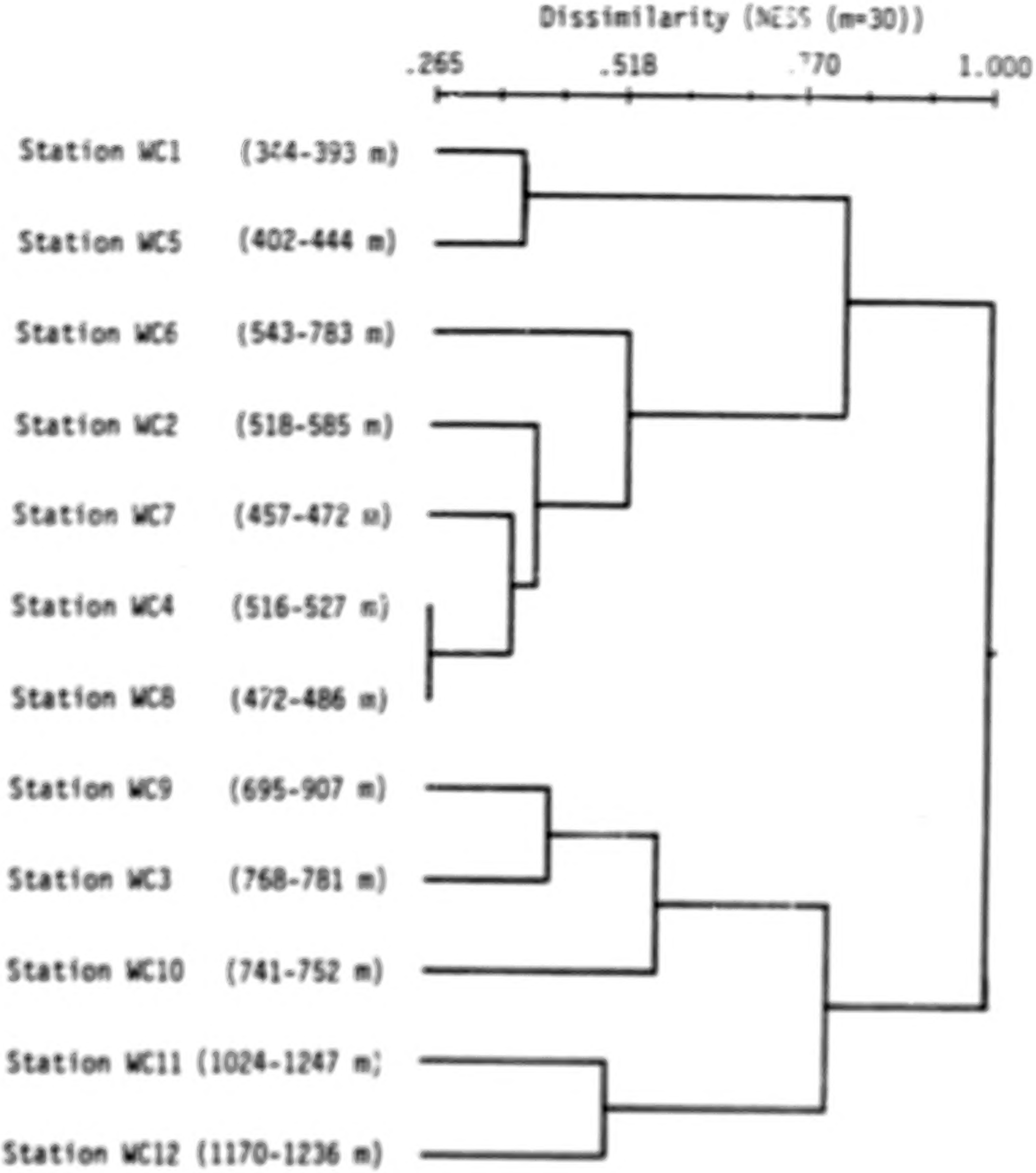


Figure 4-40. All fishes taken by trawl from the 12 stations of Cruise V clustered by NESS at 30 individuals. Comparison with the dendrogram of Figure 4-39 shows that WC6 is the only station that shifts position between the two major branches. Otherwise note WC1 and 5, and WC11 and 12, etc. are very similar.

deeper invertebrate stations and the shallower fish stations. This suggests that on the West-Central Transect invertebrates are more abundant at deeper stations and fishes at shallower stations. Thus, it would appear that during the vertical transit of 240 m (from 543 to 783 m) of trawling at Station WC6, relatively more fishes were taken at shallow depths and more invertebrates during the deeper part of the haul. This suggests that a zonal change occurs somewhere between 540 and 780 m depth.

NESS analysis was applied to all of the megafaunal invertebrates taken by trawl during Cruise III on the Central Transect, and Cruises IV and V on the East and West-Central Transects (Fig. 4-41). There is very evident isobathic clustering, but Stations C9 and C10 stand apart. Reference to the cruise log for Cruise III revealed that in both cases the trawl was filled with a huge mud lump that prevented proper sampling. In spite of the inclusion in the NESS of some stations where the trawling was not successful, there are some reasonably good clustering with possible zonal separations. Stations C5 and C11 tend to reflect the Mesoabyssal. Stations WC1, E1B, E1C, E1, E1A, C1, and WC5 compare well with the Shelf-Slope Transition. Most of the rest of the stations appear to be horizons of the Archibenthal Zone with the exception of Stations C4, C8, WC11, and WC12, which are very likely Upper Abyssal, as their species lists also demonstrate.

The bathymetric distributions of some of the dominant species of fishes and invertebrates found on the East Transect that account for the clusters shown above are displayed in histograms in Figures 4-42, 4-43, and 4-44. Recall that the depth range of the E1 isobath is about 350 m, of E2 is 620 m, and of E3 is about 850 m. There is little overlap of isobaths by the dominant species, even though some species may have wide bathymetric ranges (note Dibranchus atlanticus in particular). The decapods shown in Figure 4-43 appear to have sharply limited bathymetric distributions; however, it should be noted that the penaeid shrimp Penaeopsis serrata lives at shallower depths in the Shelf-Slope Transition Zone, whereas Benthesicymus bartletti penetrates much deeper than the 850 m depth of the E3 series of stations. The carideans in Figure 4-43 on the other hand, have distinctive depth limits that fall within the station depths shown. Essentially the same may be said about the brachyuran crabs

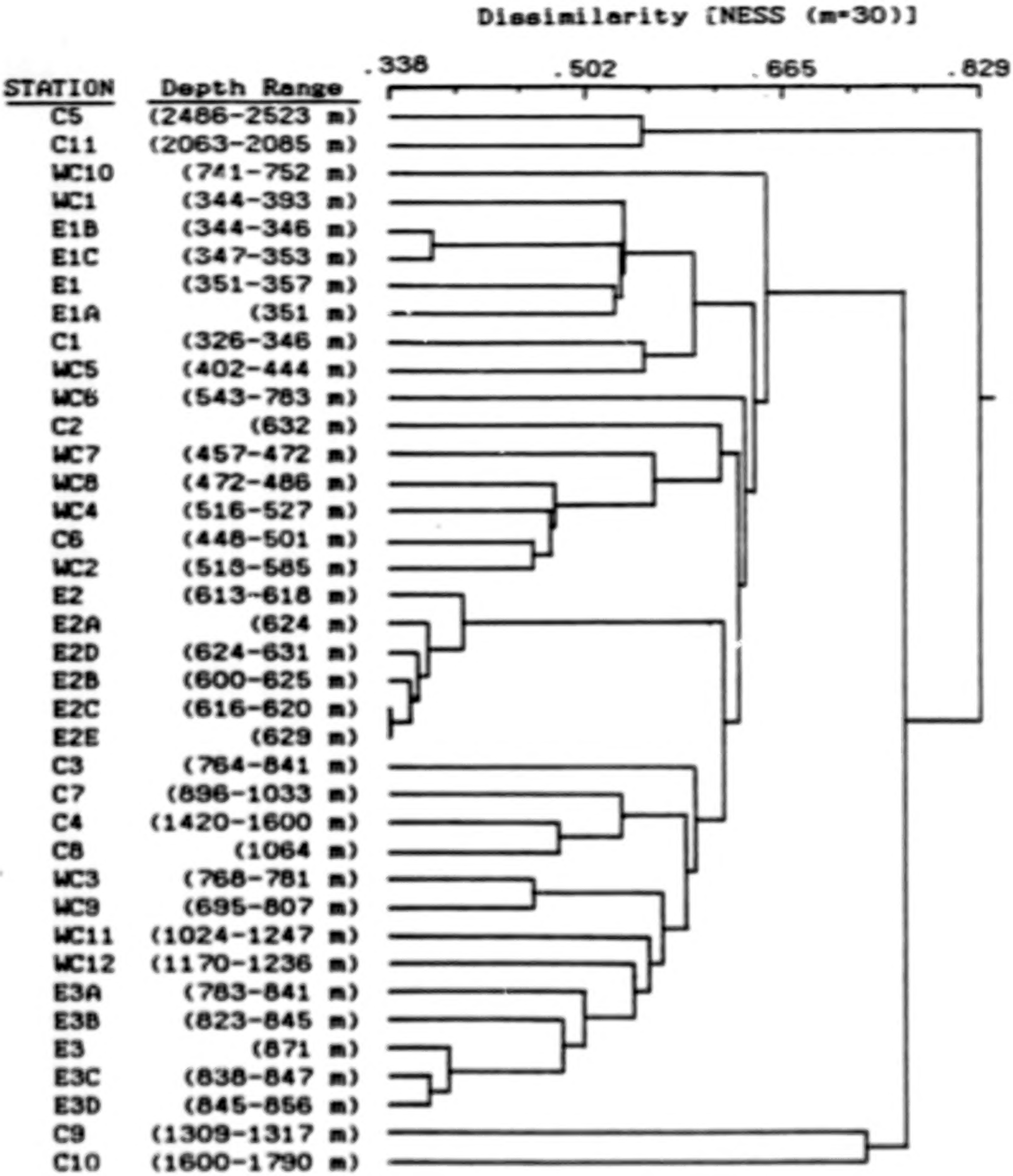


Figure 4-41. All invertebrates from Cruises III (Central Transect), IV (East Transect), and V (West-Central Transect).

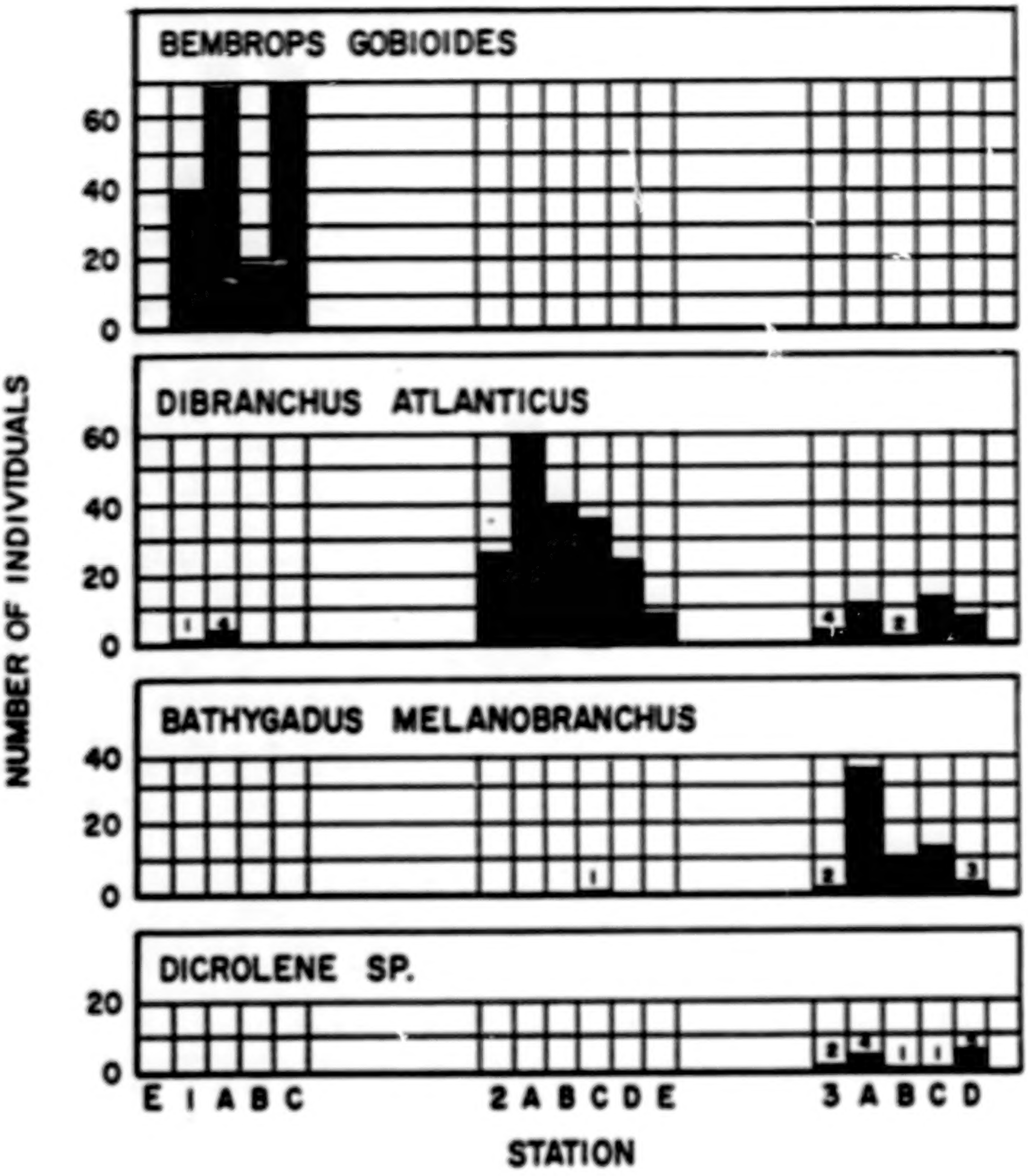


Figure 4-42. Numbers of individuals of four common fishes collected from the 15 isobathymetric stations of Cruise IV. All stations in each of the three groups are about the same depth (E1 series around 350 m; E2 series about 620 m; and the E3 series about 850 m).

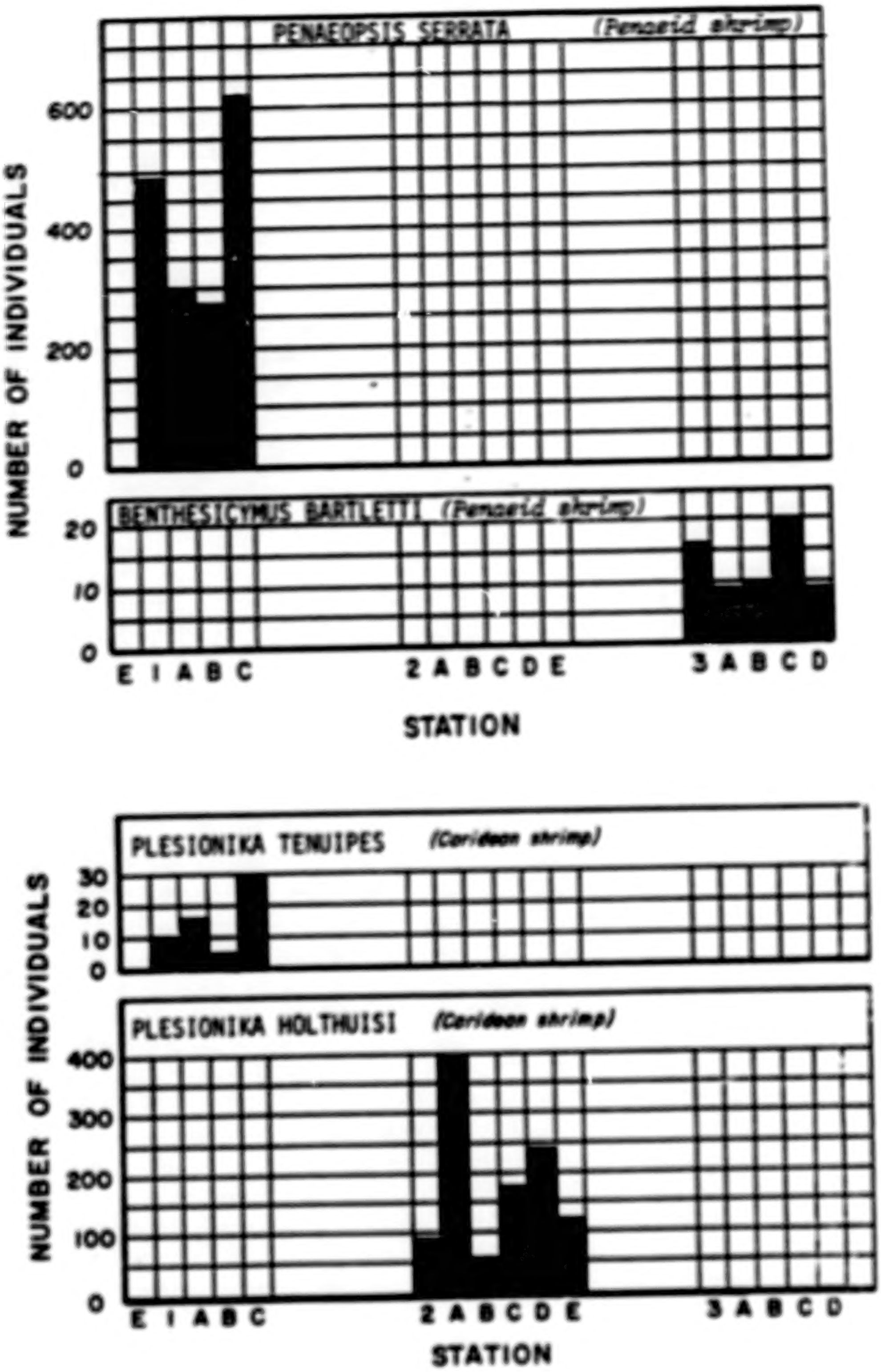


Figure 4-43. Results of isobathymetric trawling during Cruise IV on the Eastern Transect. Histograms show the number of individuals of two penaeid shrimp species (upper pair) taken on three isobaths; the lower pair show the same discrete depth distributions of two caridean species at the various stations on the same three isobaths as shown above. Depths as in Figure 4-87.

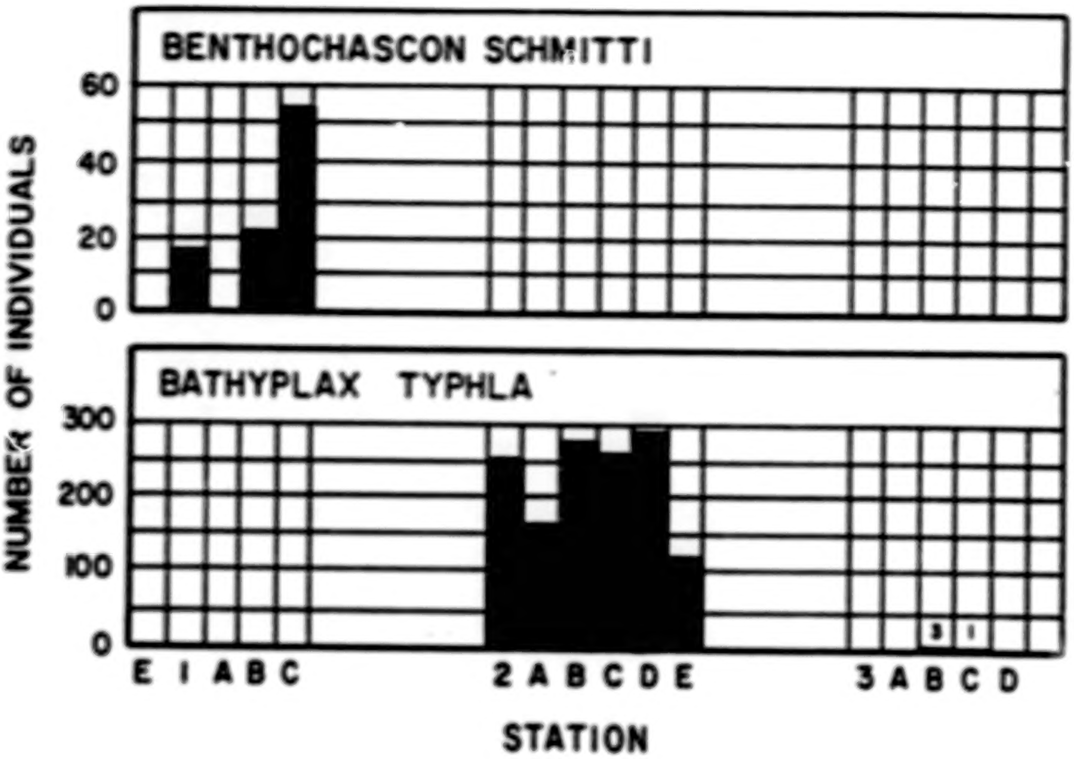


Figure 4-44. Numbers of individuals of two common brachyuran crab species collected from the 15 isobathymetric stations of Cruise IV. Depths as in Figure 4-87.

shown in Figure 4-44. The few individuals of the very common Bathyplax typhla shown in the E3 series were very young individuals. The young of brachyurans are often found in reduced numbers at depths deeper than those occupied by adults.

It has long been suspected that the chirostylid Uroptychus nitidus lives among the branches of the gorgonian coral Chrysogorgia agassizii. The concordance in their station and isobathic distributions, as seen in Figure 4-45, lends credence to the belief. Also, the finding of a whole flat-backed lobsterette (Stereomastis sculpta) in the stomach of an eel (Synaphobranchus oregoni) led to a debate as to whether the event was happenstance or a normal predator/prey relationship. The concordance in their bathymetric and numerical distributions seen in Figure 4-46 makes the latter relationship plausible.

Chi-Square Analyses

A summary of the results for fishes of the isobathymetric sampling on the Eastern Transect during Cruise IV is shown in Table 4-8. Here we see a separation of the "starts and stops" for species which form the basis for the chi-squared analysis of zonal distribution discussed in the next section. Results from Stations WC11 and 12 are added for comparison with a deeper depth band.

For detecting faunal boundaries we have utilized the method devised by Backus et al. (1965) and employed more recently by Gage (1986) in examining bathymetric zonation of the benthic fauna in the Rockall Trough south of the Wyville Thomson Ridge. In essence the method uses presence/absence data to plot the distribution of the sum of first-plus-last captures at between-station intervals on a transect having a gradient of increasing depth. If indeed the zonal concept is an acceptable way of describing bathymetric distribution, where areas of faunal homogeneity are separated by narrow regions of species change, upper and lower limits should occur concurrently more frequently than expected on the basis of chance. Comparisons were made between expected values for collection intervals and those actually observed using the chi-square test and obtaining probability levels. The chi-squared values, which can be thought of as indices of faunal change for each depth interval, are then

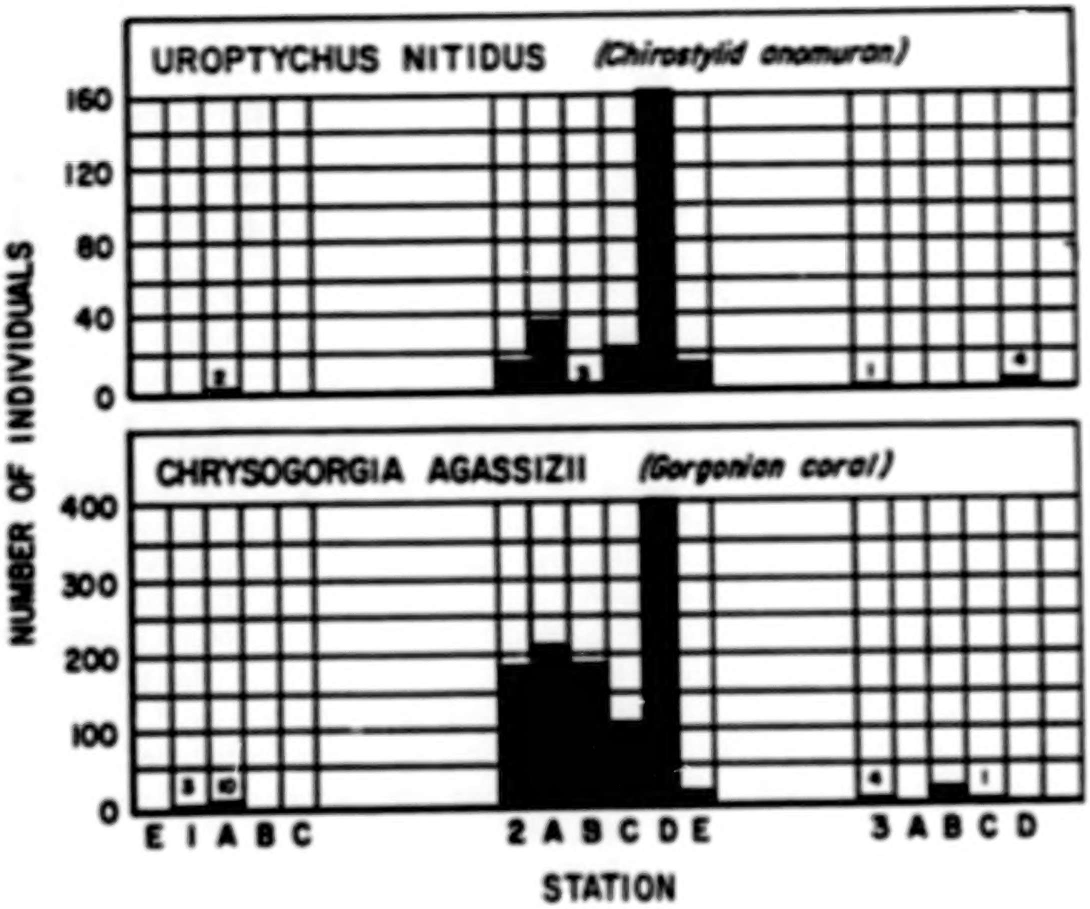


Figure 4-45. The depth and station distribution patterns of a gorgonian coral and chirostylid decapod as shown in the figure from 15 stations of Cruise IV on the Eastern Transect lend further credence to the conclusion that the anomuran lives in close association with the gorgonian which builds its holdfast in the soft sediments.

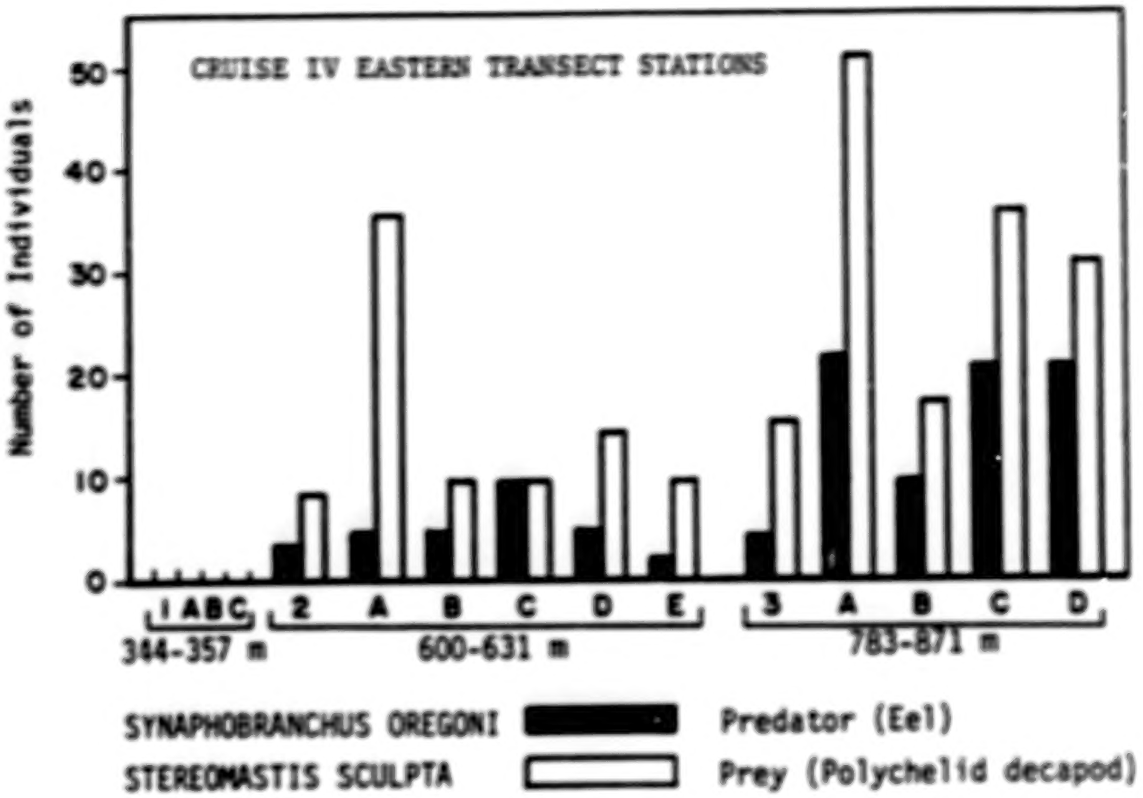


Figure 4-46. The belief that the eel preys upon the polychelid is reinforced by the concordance in their distribution among 15 stations of Cruise IV on the Eastern Transect. Note also that at most stations the prey is more abundant than the presumed predator.

Table 4-8. Summary of starts and stops of fishes trawled on the isobathymetric series of 15 stations on the Eastern Transect during Cruise IV.

Fish	Isobathymetric Transect Analysis				
	E1 (A,B,C) Transect		E2 (A,B,C,D,E) Transect		E3 (A,B,C,D) Transect
a) Transect depth range	344-357 m		613-629 m		783-871 m
b) No. of fish species taken on transect	38		36		30
c) No. of species taken at 3 or more (2 on WC) stations on transect	17		13		13
Percent of total	40%		36%		43%
d) No. of species present at E1 but not E2 "Stops"	30				
e) No. of species present at E2 but not E1 "Starts"			28		
f) No. of species common to E1 and E2		8			
Percent of total species		14%			
g) No. of species present at E2 but not E3 "Stops"			17		
h) No. of species present at E3 but not E2					15
i) No. of species common to E2 and E3				14	
Percent of total species				30%	
j) No. of species common to E1 and E3	2				2

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plotted against depth on the abcissa. Peaks in the graph mark depth intervals of maxima in the rate of faunal change. Valleys on the graph are interpreted as being relatively homogeneous, a fact that our isobathymetric sampling tended to demonstrate.

The chi-squared analysis of the distribution of fish species together with species recruitment curves are shown in Figures 4-47 through 4-52. All of the peaks above the alpha line are significant and indicate depth intervals of high species flux. In other words, they mark the depth-location of boundaries between zones. The valleys on the other hand position the zones where the species composition of the slope is uniform. On the Central Transect there are strong peaks at depths around 450-550 m, 675-750 m, 1000 m, and 2200 m (Fig. 4-48). These are close to those designated as faunal breaks for the northern Gulf of Mexico by Pequegnat (1983). Note the corresponding upsweeps in species numbers in the recruitment curve in Figure 4-47. Chi-squared and species recruitment values for fishes on the Western Transect are shown in Figures 4-49 and 4-50. Again there are peaks around 450, 700, and 1000 m, and deeper, but the latter depths are not reliable because of the limited amount of sampling at deeper depths on this transect. For the Eastern Transect, peaks occur around 300, 500, 1000 and 2000 m (Fig. 4-52); again, little sampling occurred at depths at or greater than 1000 m.

Results for the invertebrate chi-square analysis are presented in Figures 4-53 through 4-58. The chi-squared analysis of invertebrate species on the Central and Western Transects differs from that for fishes on these transects in that only one major peak is found on each transect. On the Central Transect the major peak lies between 850 and 1050 m depth, with minor peaks at 650-700, 1350, and one beginning at 2250 m (Fig. 4-54). The recruitment curve shows a weak increase at 625-650, a strong one at 775 m, one beginning at 1000 m, and others at 1400 and 2400 m (Fig. 4-53).

The invertebrate chi-squared values on the Western Transect are much more clearly defined than those on the Central Transect at depths less than 1300 m (Fig. 4-56). The first peak is at 450 m, followed by a very strong one between 700 and 750 m, a smaller one at 1000 m and another near 1300 m. The very limited sampling at depths greater than 1250 or so m on

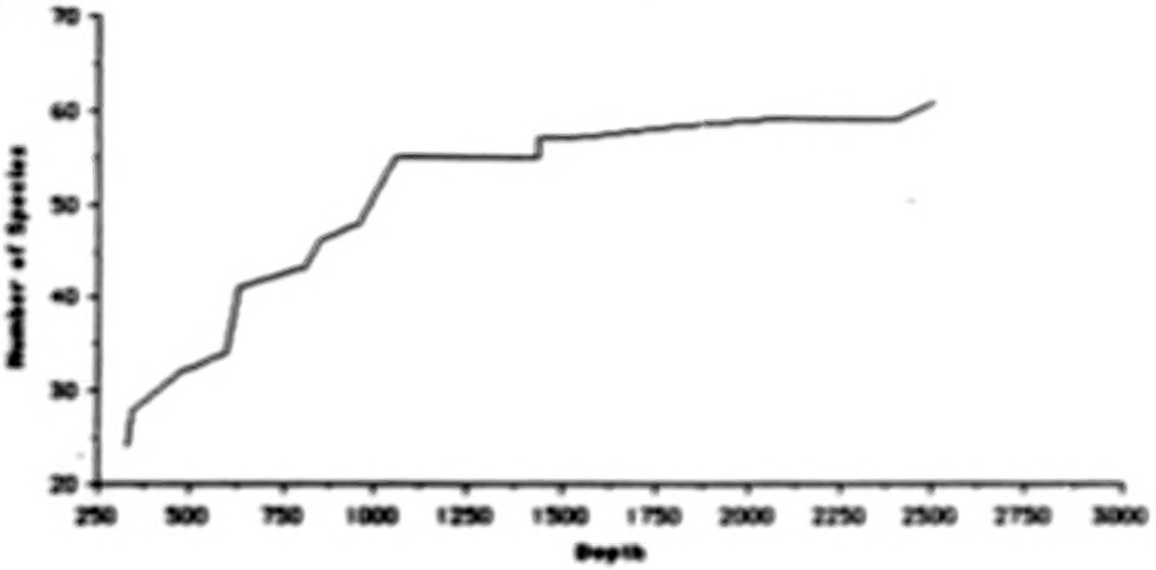

Figure 4-47. Species recruitment curve for fish species taken at all stations on the Central Transect.

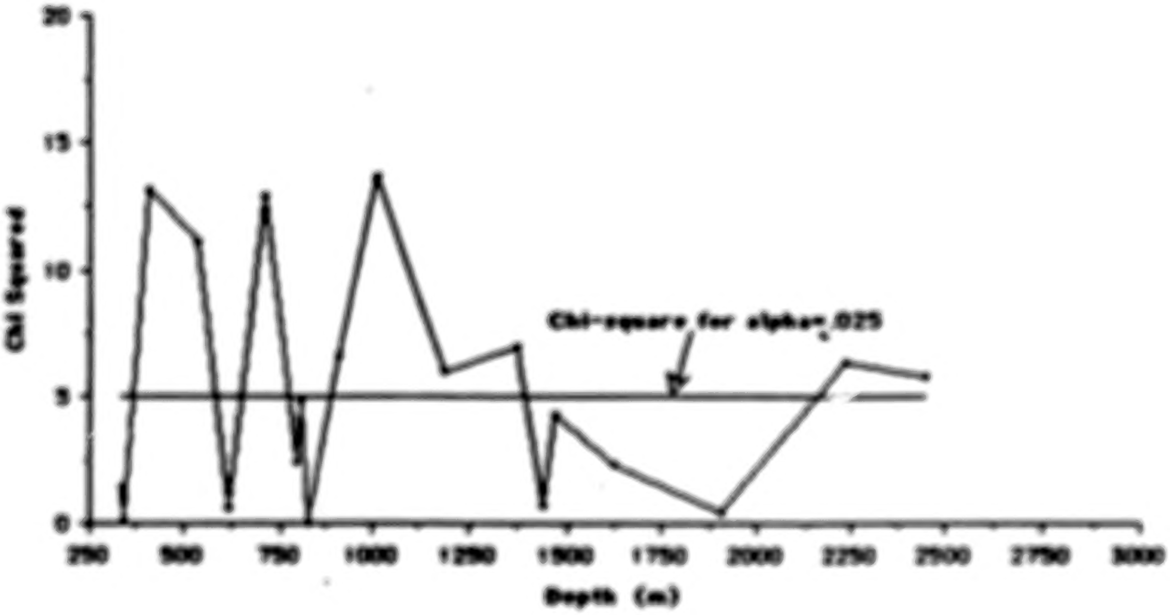

Figure 4-48. Chi-squared values for fish species taken on the Central Transect. Peaks above alpha line are depth intervals of high rate of species change.

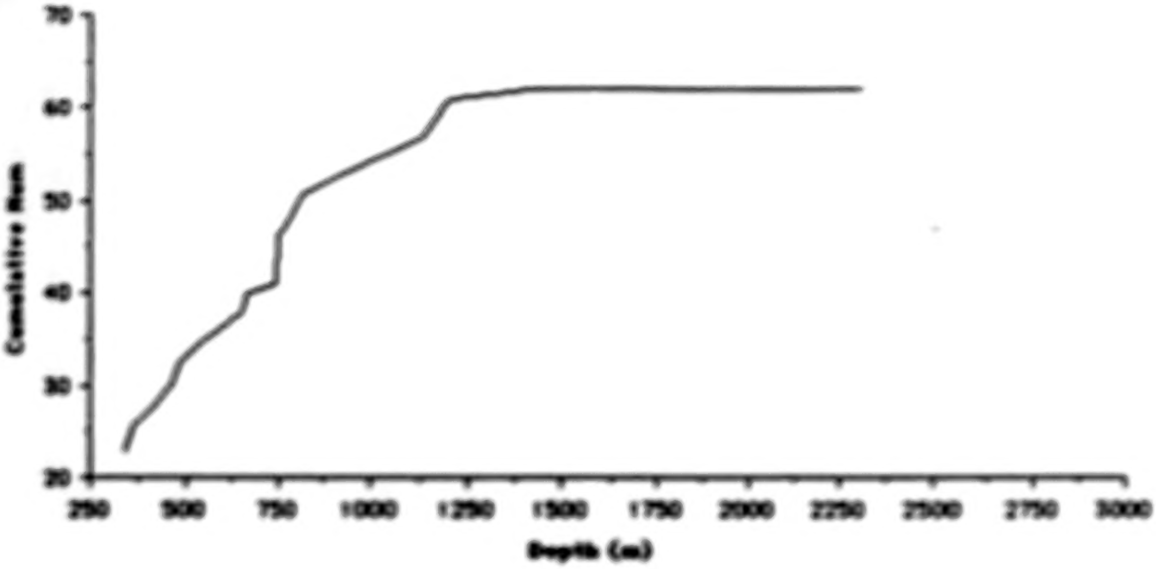

Figure 4-49. Species recruitment curve for fish species trawled on the Western Transect.

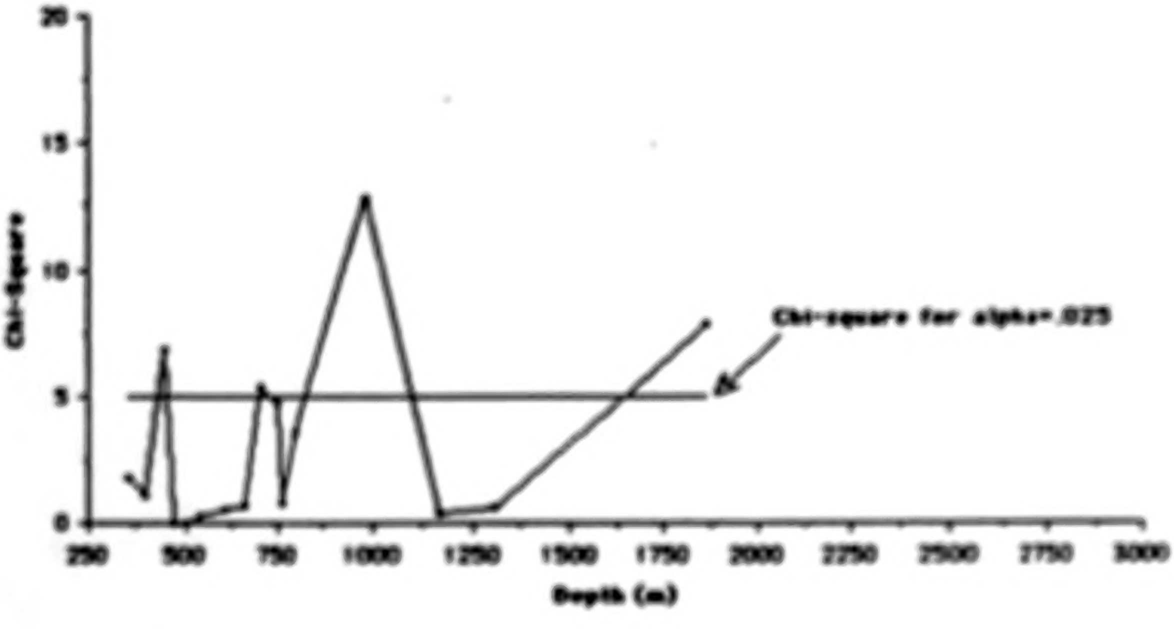

Figure 4-50. Chi-squared values for fish species taken on the Western Transect.

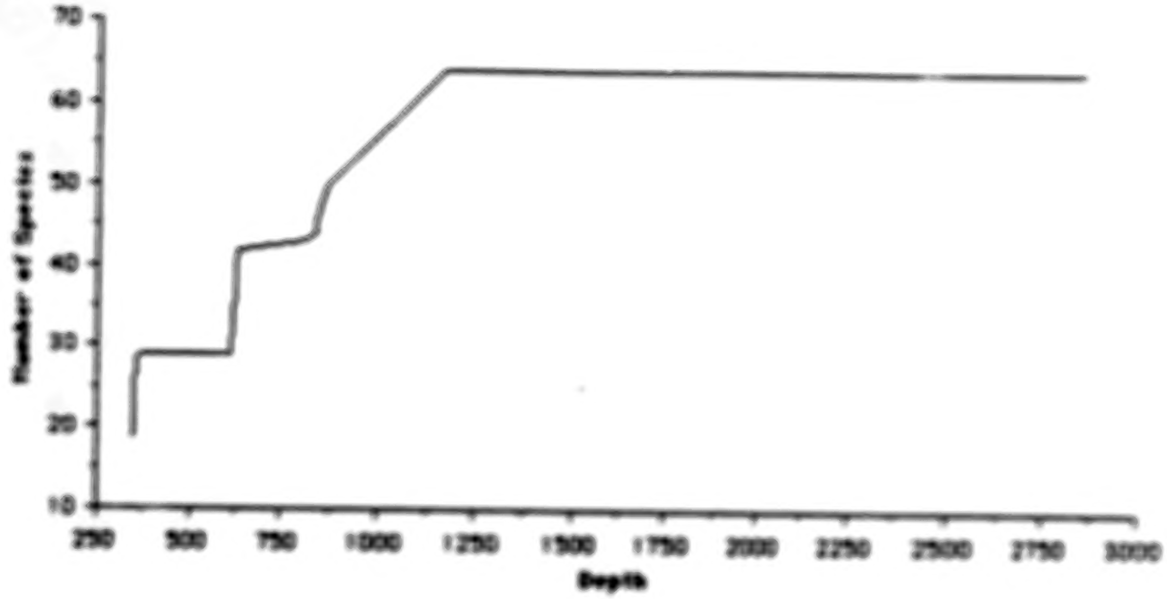

Figure 4-51. Species recruitment curve for fish species trawled on the Eastern Transect.

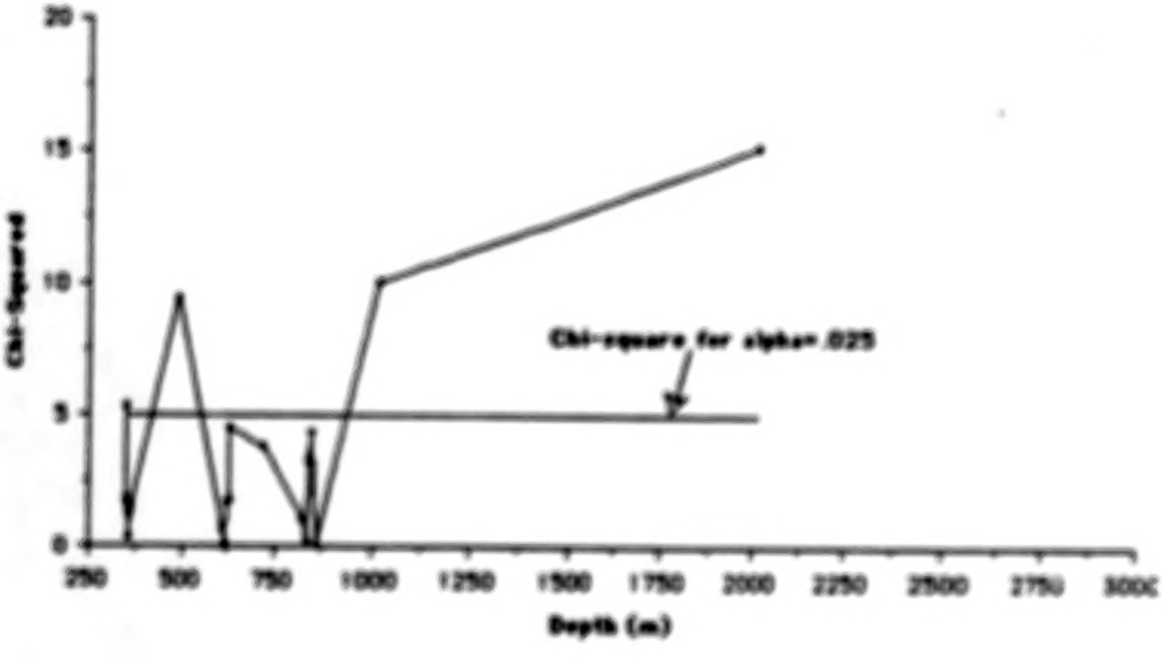

Figure 4-52. Chi-squared values for fish species taken on the Eastern Transect.

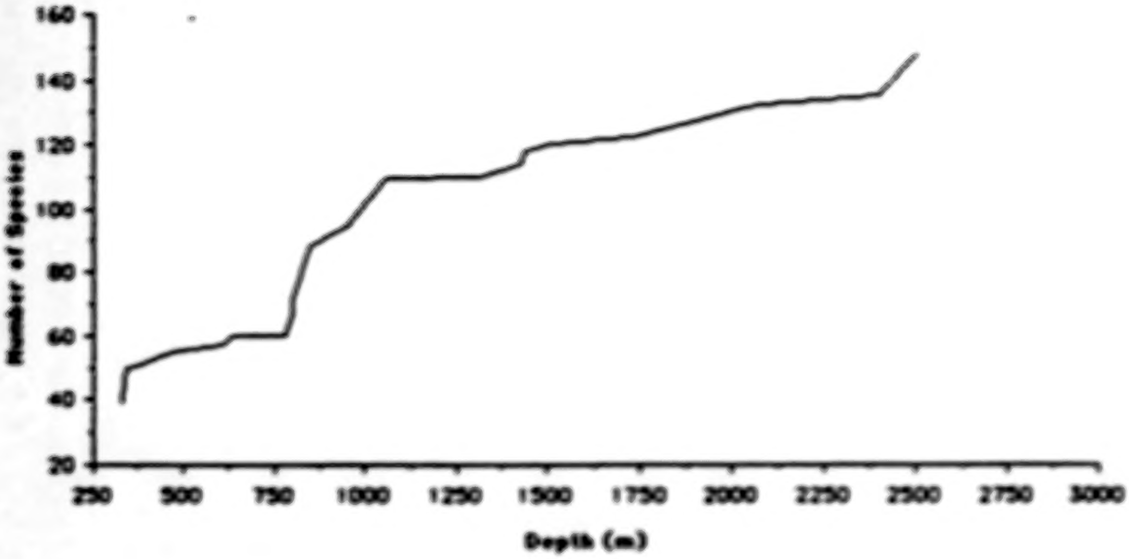

Figure 4-53. Species recruitment curve for invertebrate species trawled from the Central Transect. Compare with Chi-square values below.

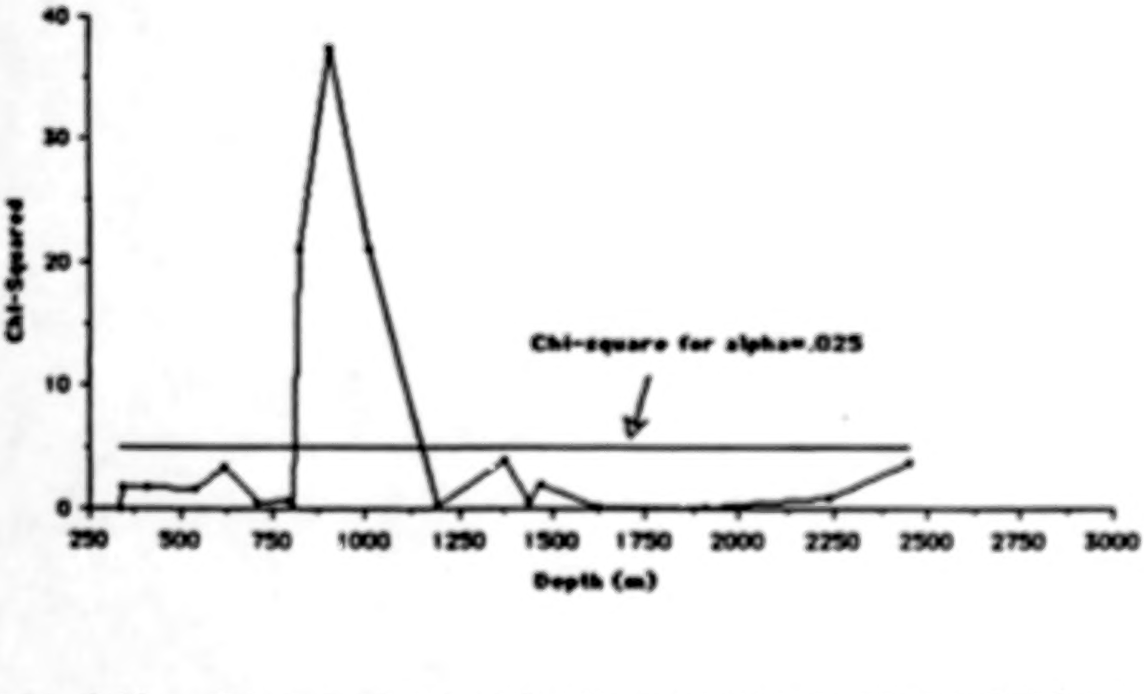

Figure 4-54. Chi-squared values for invertebrate species trawled from the Central Transect.

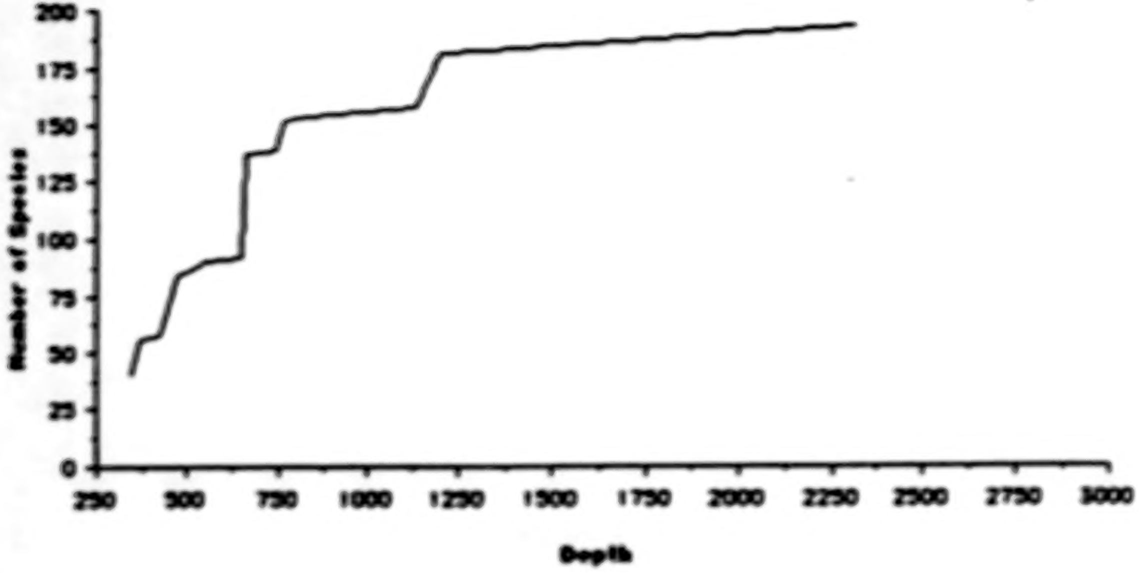

Figure 4-55. Species recruitment curve for all invertebrates trawled on the Western Transect.

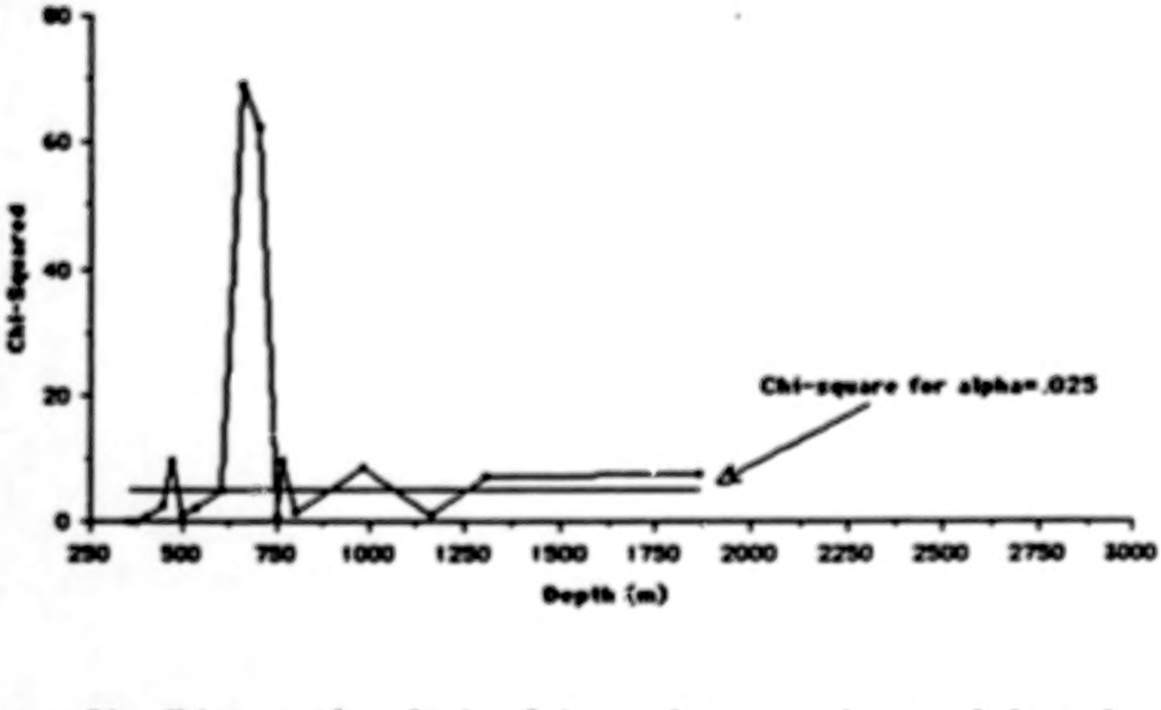

Figure 4-56. Chi-squared analysis of invertebrate species trawled on the Western Transect.

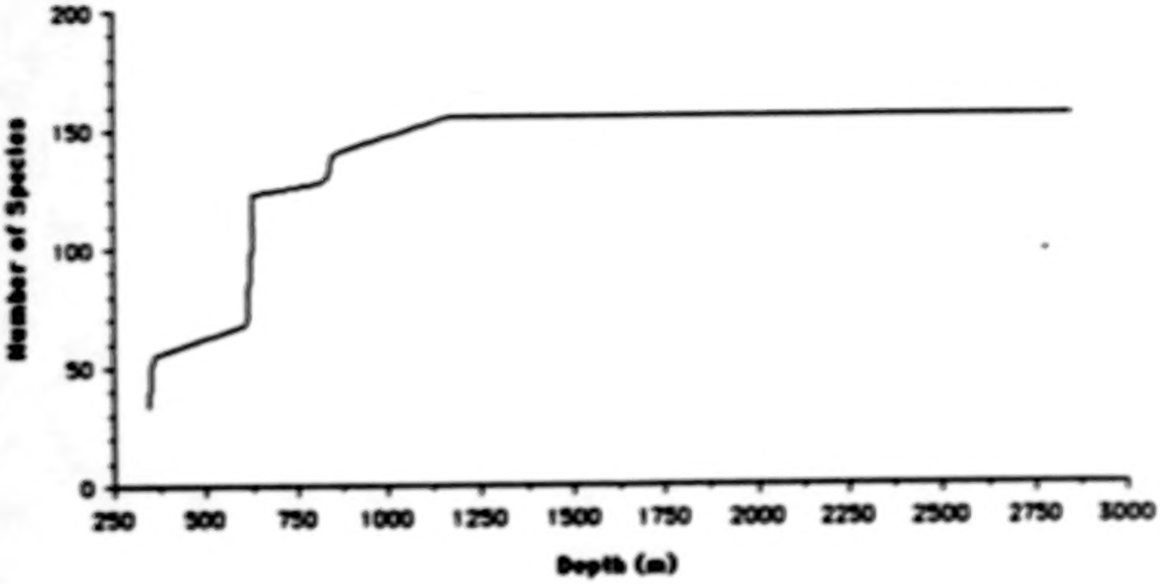

Figure 4-57. Species recruitment curve for all invertebrates trawled on the Eastern Transect.

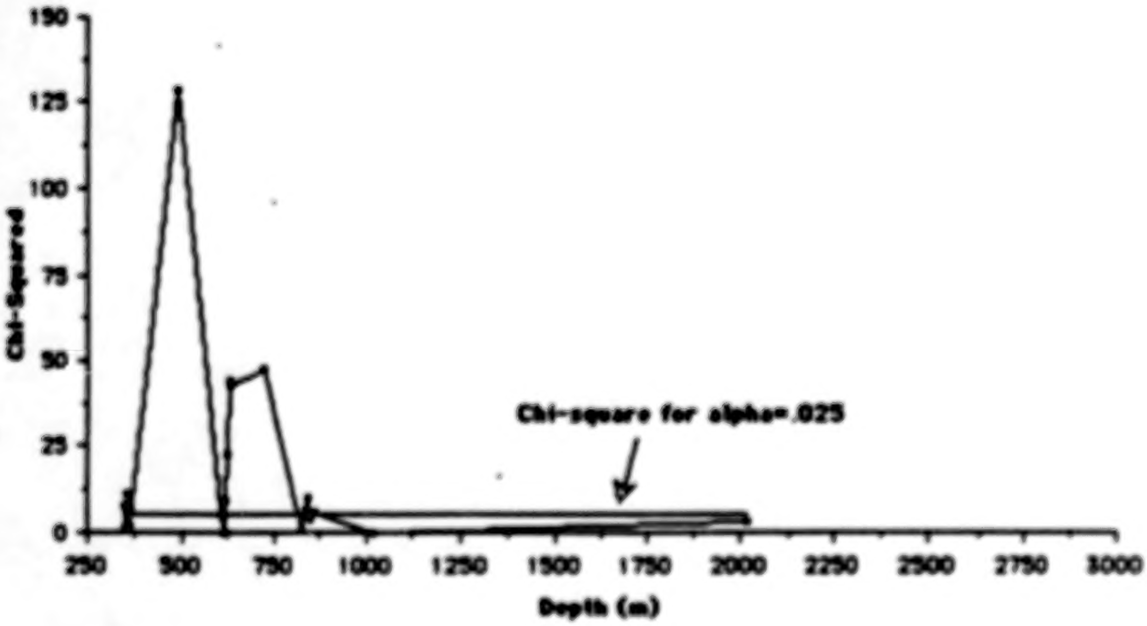

Figure 4-58. Chi-squared analysis of invertebrate species trawled on the Eastern Transect.

this transect make further analysis unreliable. The species recruitment curve has very pronounced increases that aid one in interpreting the chi-squared values (Fig. 4-55).

For the Eastern Transect, the major faunal discontinuities are indicated for the 500 and 625 to 750-m depth zones (Fig. 4-58). The species recruitment curve has the most pronounced increase at about 625 m (Fig. 4-57).

4.3.3 MAJOR INVERTEBRATE GROUP DESCRIPTIONS

Below we discuss the data obtained for the major invertebrate groups collected by trawling. Species accounts are provided for selected decapod crustaceans in Section 4.3.4. Distribution and life history descriptions are given for selected individual fish species (rather than group) in Section 4.3.5.

4.3.3.1 *Porifera*

Seventeen species of sponges were collected in the trawl. The five most abundant species were the small *Polymastia sol* (329-2857 m), *Thenea* sp. (612-1203 m), *Thenea* sp. A (621-2504 m), *Tethya* sp. (612-1203 m), and *Hyalonema* sp. (479-1510 m).

4.3.3.2 *Coelenterata*

Hydrozoa

Five species of hydrozoan polyps were collected in the trawl. The three most abundant were *Lytocarpia bispinosa* (345-871 m), *Eudendrium eximium* (618-871 m), and *Cladocarpus tenuis* (618-629 m).

Anthozoa

Antipatharia and Ceriantharia. Three undescribed species of *Antipatharia* and one species of *Cerianthid* were taken in small numbers from the upper slope.

Alcyonaria. Thirteen species of alcyonarians were collected in the trawl. The majority of these were gorgonacean corals of which *Chrysogorgia agassizii* and *Acanella eburnea* were most abundant. *Chrysogorgia* was found at 15 stations ranging in depth from 350 to 1170 m, and *Acanella* occurred at 11 stations ranging in depth from 600 to 2857 m.

Actiniaria and Zoanthidia. Among the sea anemones the species *Actinauge longicornis* was by far the most abundant. It has a very wide depth range from 329 to 2500 m and a wide geographic range, being an important component of the upper slope fauna in the North Atlantic (Maciolek et al. 1986).

Zoanthidians were common epizoans on pagurid decapods.

Scleractinia. Seven species of stony corals were collected in the trawl. The most abundant of these were *Deltocyathus italicus* (551-1203 m); *Caryophyllia ambrosia caribbeana* (774-1203 m); and *Stephanocyathus diadema* (964-1510 m).

4.3.3.3 *Annelida (Polychaeta)*

Sixty-five species of polychaetes were collected in the trawl. The two most abundant species by far were the onuphid *Hyalinoecia tubicola* (612-1510 m) and the eunicid *Eunice noegica* (350-1064 m), followed by the ampharetid *Isolda pulchella* (612-663 m), the polynoid *Eunoe* sp. A (474-1510 m), the sigalionid *Ehlersileanira incisa* (479-751 m), and the polynoid *Eunoe hubrechti* (368-663 m).

4.3.3.4 Mollusca

Bivalvia

Forty species of bivalves were collected in the trawl. Fifteen of these species were represented by only one or two individuals, and only 12 of the remaining 25 species were represented by 10 or more individuals. The most abundant of the 12 were *Propeamussium* sp. A (774-1510 m), sp. C (612-2400 m), and sp. D (338-1438 m); *Amygdalum* cf. *politum* (345-1135 m), *Anodontia* cf. *philippiana* (342 m), *Lithophaga* cf. *antillarum* (627-1203 m), and *Propeamussium dalli* (338-1438 m).

Gastropoda

Forty-five species of gastropods were collected in the trawl. Only eight species were represented by 10 or more individuals. In fact 17 species were represented by a single individual. The most abundant gastropod species were *Leucosyrinx tenoceras* (774-1510 m), *Buccinum canetae* (612-964 m), *Hyalorisia galea* (338-774 m), *Solariella lamellosa* (612-629 m), *Oocorys sulcata* (2074-2504 m), and *Scaphander watsoni* (329-346 m).

Cephalopoda

Thirteen species of cephalopods were collected in the trawl. Most of the species were represented by one or two individuals, but five species are worthy of specific mention: *Alloposus mollis* (354-663 m), *Rossia bullisi* (342-621 m), *Benthocropus januari* (464-551 m), and *Pholidoteuthis adami* (627-1170 m).

Scaphopoda

Five species of tooth shells were collected in the trawl. The most abundant species were *Dentalium perlongum*, which has a wide depth range from 840-2400 m, *Laevidentalium callipeplum* that occurs only at shallow depths from 345 to 368 m, and Dentalium circumcinctum, which occurs at intermediate depths around 840 m.

4.3.3.5 Arthropoda

One hundred and sixty-three species of benthic and benthopelagic crustacea and other arthropods were collected in the trawl from the major transects and isobathymetric station-lines established in this study (see Table 4-9). Fifty-nine species or 36% of the 163 species were collected for the first time in Cruises IV and V. Forty of the 59 species were decapods. Most of these were either galatheid anomurans or brachyuran crabs, both of which doubled their species totals over those of the first three cruises. Several of these are either new species or represent first-time collections in the Gulf or the entire western Atlantic.

About 79% of the arthropods were decapods (Table 4-9), and of these Anomura yielded the most species, followed by the Caridea. Although some Isopoda and Amphipoda were collected with the trawl, the overwhelming majority of these crustaceans, many of which are new species, were collected by the box corer and are therefore discussed in the Macrofauna section of this report.

Whereas we observed from the first three LGL cruises that 53% of the arthropod species then collected extend their bathymetric range deeper than the 1000-m isobath, an analysis of data from all cruises reveals that only 36% are found at or below this isobath. This marked decrease may have considerable ecological significance. The principal sampling effort during Cruises IV and V was directed toward isobathymetric station placement, i.e., stations were arranged along horizontal lines that varied in depth as little as possible. Moreover, most of these isobathymetric station-lines (essentially horizontal transects) were run at depths considerably less than 1000 m. Since all of these depths were sampled in the three previous cruises without obtaining the first-time species found in Cruises IV and V, it is suggested that the distribution of these species is best described as patchy. The patches are of unknown size but are probably related to local factors such as sediment texture and chemistry. The existence of such patches is best revealed by isobath

Table 4-9. Megafaunal arthropods collected by trawl during Cruises I, II, III, IV, and V of the LGL study. (Numbers in parentheses are the number of species from Cruises I-III only.)

Taxa	No. of Species	% of all Arthropods	No. of Species at or below 1000 m	% of Species below 1000 m
CRUSTACEA				
Cirripedia	16 (7)	10	5	31
Isopoda	8 (2)	5	2	25
Amphipoda	8 (5)	5	6	75
Decapoda	129 (89)	79		
Penaeidea	13 (11)		7	54
Caridea	33 (24)		12	36
Anomura	41 (28)			
Paguridae	10 (9)		5	50
Porcellanidae	1 (1)		0	0
Chirostylidae	2 (2)		2	100
Lithodidae	1 (1)		1	100
Galatheidae				
Munida	10 (6)		3	30
Munidopsis	17 (9)		5	29
Macrura	11 (9)			
Polychelidae	4 (4)		3	75
Nephropidae	5 (3)		2	40
Scyllaridae	1 (1)		0	0
Axiidae	1 (1)		0	0
Brachyura	30 (17)		5	17
Stomatopoda	1 (1)	1	0	0
CHELICERATA				
Pycnogonida	2 (1)	1	1	50
	163 (104)	100	59	36

sampling. Beyond doubt these results are another example of the species-sample-effort curve, but it does not follow that isobathymetric sampling below 1000 m would reverse the above percentages. It would not be expected, for example, that such sampling would add substantial numbers of species of such groups as Brachyura and *Munida* galatheids whose major population centers are known to be shallower than the 1000-m isobath. Moreover, it is commonly believed that ecological conditions are more uniformly distributed below 1000 m than above. And most groups of megafaunal invertebrates exhibit a marked decrease in diversity with increasing depth, as is noted later in this section.

Pycnogonida

Two species of pycnogonids were collected in the trawl. Only one individual of each species (*Pallenopsis tydemani caraibica* and *Pallenopsis scoparia*) was taken.

Cirripedia

Sixteen species in 12 genera of barnacles were collected in trawl samples. Two species live attached to the carapace of crabs. Of these two *Trilasmis kaempferi inaequilaterale*, which was found on three crab species (*Chacellus filiformis*, *Acanthocarpus alexandri*, and *Geryon quinquedens*), was much more common than *Octolasmis geryonophilia* which apparently occurs only on *Geryon quinquedens*. The four most abundant species, aside from the above, in descending order were *Verruca floridana* (depth range from 328-750 m), *Arcoscalpellum portoricanum intonsum* (depth range from 328-750 m), *Amigdoscalpellum semisculptum* (depth range 465-2050 m), and *Verum idioplax* with a depth range of 750-1500 m. Only one specimen of *Verruca euglypta* was collected in the west-central region, but it proved to be a first record for the Gulf of Mexico.

Isopoda

Eight species of isopods were collected by the trawl. Of these only one species, *Bathynomus giganteus* (479-1170 m) has been described. There were three undescribed species in the genus *Aega* and one species each in the genera *Cirolana*, *Meinertia*, *Rocinela*, and *Lironeca*. The latter, *Lironeca* sp. 286, was found to be a parasite of fish.

Amphipoda

Eight species of amphipods were collected by the trawl. Six of these were undescribed species in the genera *Anonyx*, *Epimera*, *Euronyx*, and *Valettiopsis*, while two were given tentative identifications, *Oediceroides* cf. *abyssorum* (1170-1440 m), and *Trischizostoma* cf. *longirostre* (1170-2857 m).

Stomatopoda

Only one species of stomatopod, *Squilla edentata*, was collected in the trawl. Only five individuals were taken from a single station (C1 at 329 m) on the Central Transect. It is known to be more abundant at shallower depths.

Decapoda

Below we provide a summary of the major groups of decapods. These accounts are supplemented by representative species accounts which can be found in Section 4.3.4.

Natantia:Penaeidea. Thirteen species of benthonic penaeid shrimps were collected in this study. *Penaeopsis serrata* was by far the most abundant penaeid species yielding 2896 individuals at 11 stations. The depths at 10 of these stations average 375 m and the species was not found below 465 m. The species averaged 260 individuals at the shallow stations and only two at the deeper station (Fig. 4-59). It was found on all three major transects. The population density of *P. serrata* ranged from 4 to 255 (average 138) per hectare at the shallow stations and was 14 per hectare at 465 m where it occurred at only one of 17 sampling stations of that average depth (Table 4-10). Perhaps a more realistic view of its abundance is the fact that overall it occurred at only 39% of the 28

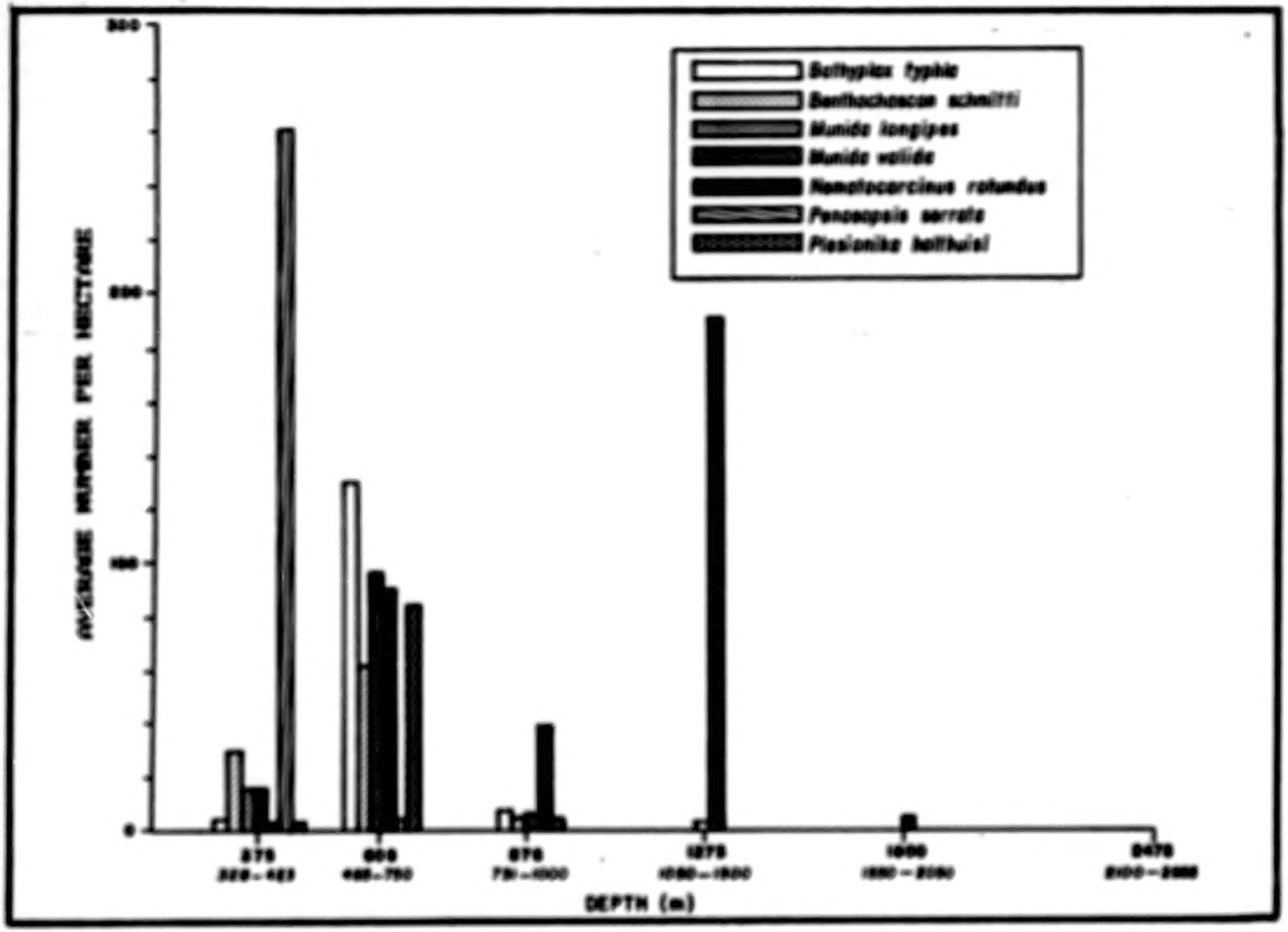

Figure 4-59. Average number of individuals of selected decapods at collecting stations in the depth intervals shown on abscissa.

stations sampled within its depth range. The dramatic reduction in its population is seen in Figure 4-104. Other more detailed facts about the biology of Penaeopsis serrata may be found in Section 4.3.4 of this report.

Table 4-10. Comparison of the five most abundant penaeid species from the LGL and TerEco studies.

LGL				TerEco		
Species	Total Collected	Ave. Density Per Hectare	Depth (m) Max. Pop.	Species	Total Collected	Depth (m) Max. Pop.
Penaeopsis serrata	[illegible]	138	375	Penaeopsis serrata	[illegible]	375
Hymenopenaeus robustus	184	6	605	Benthesicymus bartletti	[illegible]	1050
Benthesicymus bartletti	166	5	1275	Parapenaeus longirostris	[illegible]	250
Parapenaeus longirostris	80	5	375	Hymenopenaeus robustus		500
Hymenopenaeus debilis	69	4	605	Hymenopenaeus debilis	[illegible]	640

Only four other penaeid species were of sufficient abundance as to be of interest here. Hymenopenaeus robustus was the second most abundant penaeid shrimp in numbers collected. One hundred and eighty-four specimens were taken at 17 stations out of the 28 established within its depth range from 328 to 750 m (Table 4-10). This establishes it as one of the most common shrimps on the northern Gulf slope since the chances of getting one or more H. robustus within its depth range are about two out of three trawls. Its population density ranges from 1 to 20 per hectare with an average of six at those stations where it is found. Benthesicymus bartletti was third in abundance, but only a total of 166 individuals was collected, but it did occur at 20 stations ranging in depth from about 875 to 2050 m. The density of this species ranged from 1 to 39 per hectare with an average of five per hectare where it occurred. Thus, although B. bartletti did not produce as many individuals as P. serrata, it did occur at 69% of the 29 stations sampled within its depth range. A more detailed treatment of the biology of Benthesicymus bartletti may be found in Section 4.3.4 of this report. Parapenaeus longirostris was fourth in abundance with a total of 80 individuals, and it was taken only at four stations having an average depth of 375 m. Its density ranged from 1 to 15 per hectare where found. Hymenopenaeus debilis was represented by 69 individuals collected at 10 stations ranging in depth from 600 to 1275

m. The density of this species ranged only from 1 to 14 per hectare. Although the actual numbers collected of *P. longirostris* and *H. debilis* are not far apart, the chances of obtaining one or more of the latter within its depth range are about one in four, as compared with better than one in 2.5 trawls for *P. longirostris*.

The least abundant penaeids in the present collection are *Solenocera necopina* and *Hemipenaeus carpenteri*, the first is rare in the present collection because the shallowest LGL station is the deepest record for the species, and *H. carpenteri* is not well represented in part because its population maximum is considerably deeper (3300 m) than the deepest LGL station.

The genus *Hymenopenaeus* is represented in the collection by three sibling species that have some overlap in their distributions but have marked differences in population density (Fig. 4-60).

Natantia:Caridea. Thirty-three species of caridean shrimps were collected during the five cruises. Nine species were added to the list during Cruises IV and V. All were taken at depths less than 1000 m in both the West Central and Eastern Transects. Two of the nine are undescribed species, viz., a hippolytid, *Bythocaris* sp. A, taken on the West Central Transect at a depth of 1136 m, and a palaemonid in the genus *Palaemonella*, which was collected on the same transect at depths of 479 and 522 m. In addition, we have obtained first records in the Gulf for five other caridean species: the pandalid *Heterocarpus laevis* (Cruise V at 663 m); the crangonid *Metacrangon jacqueti agassizi* (Cruise III at 965 m); the crangonid *Prionocrangon pectinata* (all five cruises at depths ranging from 613 to 1206 m); the processid *Processa profunda* (Cruise IV at 367 m and Cruise V at 368 m); and the palaemonid *Periclimenes pandionis* taken on Cruise III at a depth of 632 m. In addition we have taken both a new species of Stenopodidea, *Spongicoloides* n. sp., and eight individuals of the very rare species *Richardina spinicincta*.

The most abundant of the caridean shrimps on the slope of the northern Gulf is *Nematocarcinus rotundus*, which has a wide bathymetric range from about 500 to 1550 m (Table 4-11). Its frequency of occurrence

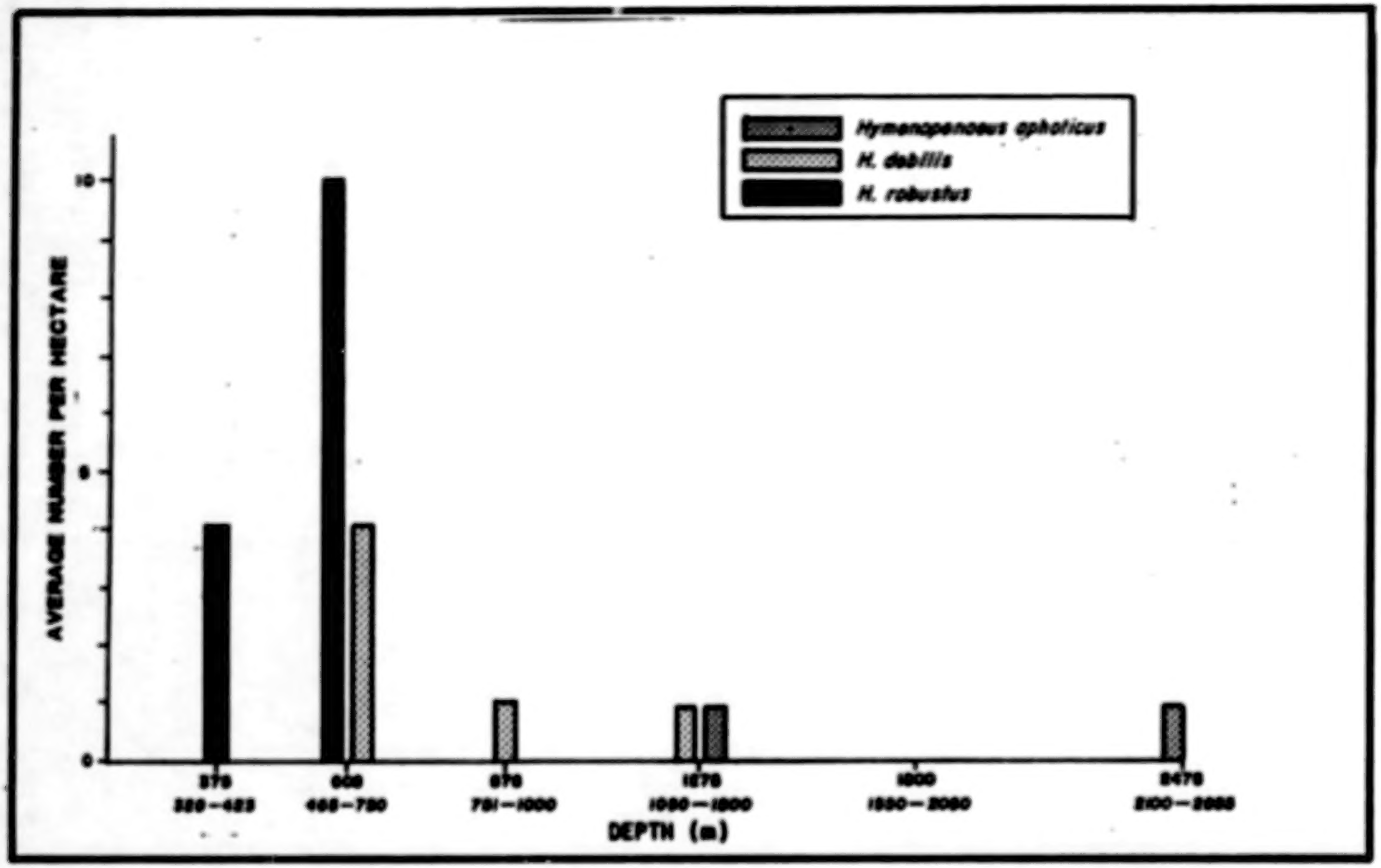

Figure 4-60. Average density (no./hectare) of three sibling species of the genus Hymenopenaeus (penaeid shrimp).

is also high having been collected at 34 of the 38 stations (89%) located within its depth range (Fig. 4-59).

Table 4-11. Comparison of the five most abundant caridean species from the LGL and TerEco studies.

LGL				TerEco		
Species	Total Collected (All Stations)	Ave. Density Per Hectare	Depth (m) Max. Pop.	Species	Total Collected (All Stations)	Depth (m) Max. Pop.
Nematocarcinus rotundus	3445	45	1275	Nematocarcinus rotundus	1480	1050
Plesionika holthuisi	1558	30	667	Plesionika holthuisi	222	650
Glyphocrangon nobilis	333	12	1250	Glyphocrangon nobilis	716	1050
Glyphocrangon aculeata	314	10	1170	Glyphocrangon aculeata	371	1150
Parapandalus willisi	240	9	375	Parapandalus willisi	295	400

Over 3400 specimens of N. rotundus were collected in such a pattern as to produce a bimodal curve of abundance, with one peak occurring between 465 and 750 m and the other between 1050 and 1500 m (Fig. 4-59). Its maximum population density of 334 individuals per hectare is found at 1135 m on the West Central Transect; however, it maintains an average density of only 45 per hectare (0.0045 individuals/m). A more detailed treatment of the biology of Nematocarcinus rotundus may be found in Section 4.3.4 of this report.

There are four species of Nematocarcinus that exist in the offshelf waters of the Gulf of Mexico. They display interesting bathymetric and geographic distribution. LGL collected two of the four species, viz., N. rotundus and N. ensifer; however, only six individuals of the latter species were taken. This is not unexpected because ensifer ranges in depth from 1650 to 3750 m with a maximum population near 2100 m (Pequegnat 1983), which are depths LGL sampled only a few times. Although the geographic ranges of N. rotundus and N. ensifer (sibling species) overlap, their bathymetric ranges do not. However, the distribution of the other two species is such as to achieve quite effective isolation. Thus, the depth range of N. cursor overlaps that of N. rotundus but it is limited to the southeastern Gulf where the latter does not occur, and whereas the depth range of N. acanthitelsonis overlaps that of ensifer, the two species do not compete because acanthitelsonis is limited to the southwestern Gulf.

The second most abundant caridean in the northern Gulf is the pandalid *Plesionika holthuisi* (Table 4-11). Its bathymetric range extends from about 365 to 850 m. Here it attains an average population density of 30 individuals per hectare, with a maximum density of 334 per hectare on the Eastern Transect at a depth of 600-620 m (Fig. 4-59). There are four siblings of *P. holthuisi* in the collection, but they are not so common. Thus, although *Plesionika acanthonotus*, *tenuipes*, *longipes*, and *edwardsii* overlap the bathymetric range of *P. holthuisi*, they either have shallow population centers or occur in larger numbers in geographic parts of the Gulf that the latter does not occupy (Fig. 4-61). The figure shows very graphically the predominance of *P. holthuisi* in the northern Gulf. A more detailed treatment of the biology of *Plesionika holthuisi* may be found in Section 4.3.4 of this report.

The glyphocrangonids *Glyphocrangon nobilis* and *G. aculeata* are the third and fourth most abundant carideans on the upper and middle slope of the northern Gulf (Table 4-11). These two species have about the same depth range (750-2058 m) and do occur at times at the same station, but *G. aculeata* has a greater frequency of occurrence, 62% of stations within its depth range as compared with 45% for *G. nobilis*. In fact, *G. aculeata* has a much more uniform distribution of population than *nobilis* in that its density ranges only from 1 to 76, whereas the latter ranges from 1 to 105. Were it not for this latter density at Station 11 (1136 m) on the West Central Transect, *G. nobilis* would probably be outranked by both *aculeata* and *alispina*. It is suggested that *G. nobilis* in particular (perhaps other species as well) may have developed a colony way of life. As in the case of the caridean genus *Plesionika*, *Glyphocrangon* is polyspecific. The present collection contains four species: *G. nobilis*, *aculeata*, *alispina*, and *longleyi* (Fig. 4-62). Both *G. nobilis* and *aculeata* seem to achieve highest average densities in the same depth unit between 1150 and 1250 m, but *nobilis* is more abundant to the west and *aculeata* to the east. A more detailed treatment of the biology of *Glyphocrangon aculeata* may be found in Section 4.3.4 of this report.

The fifth most abundant caridean is the pandalid shrimp *Parapandalus willisi* (Table 4-11). Its population density averages between 9 and 10 per hectare in its depth range of 250 to 465 m. Its density ranges from 3 to 28; it has a remarkable frequency of occurrence, having been captured

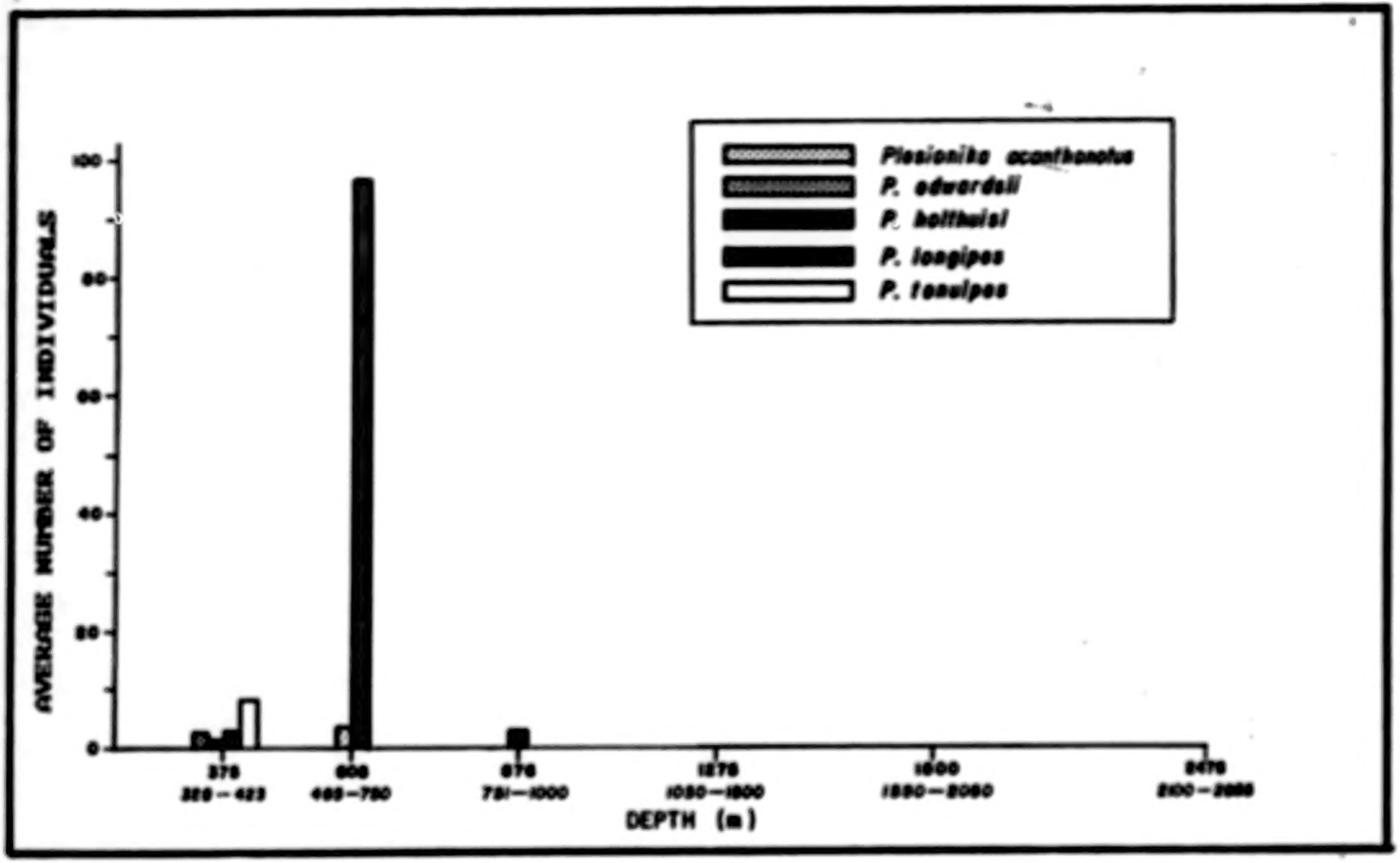

Figure 4-61. Average number of individuals per station of species in the genus Plesionika. Note depth intervals on abscissa.

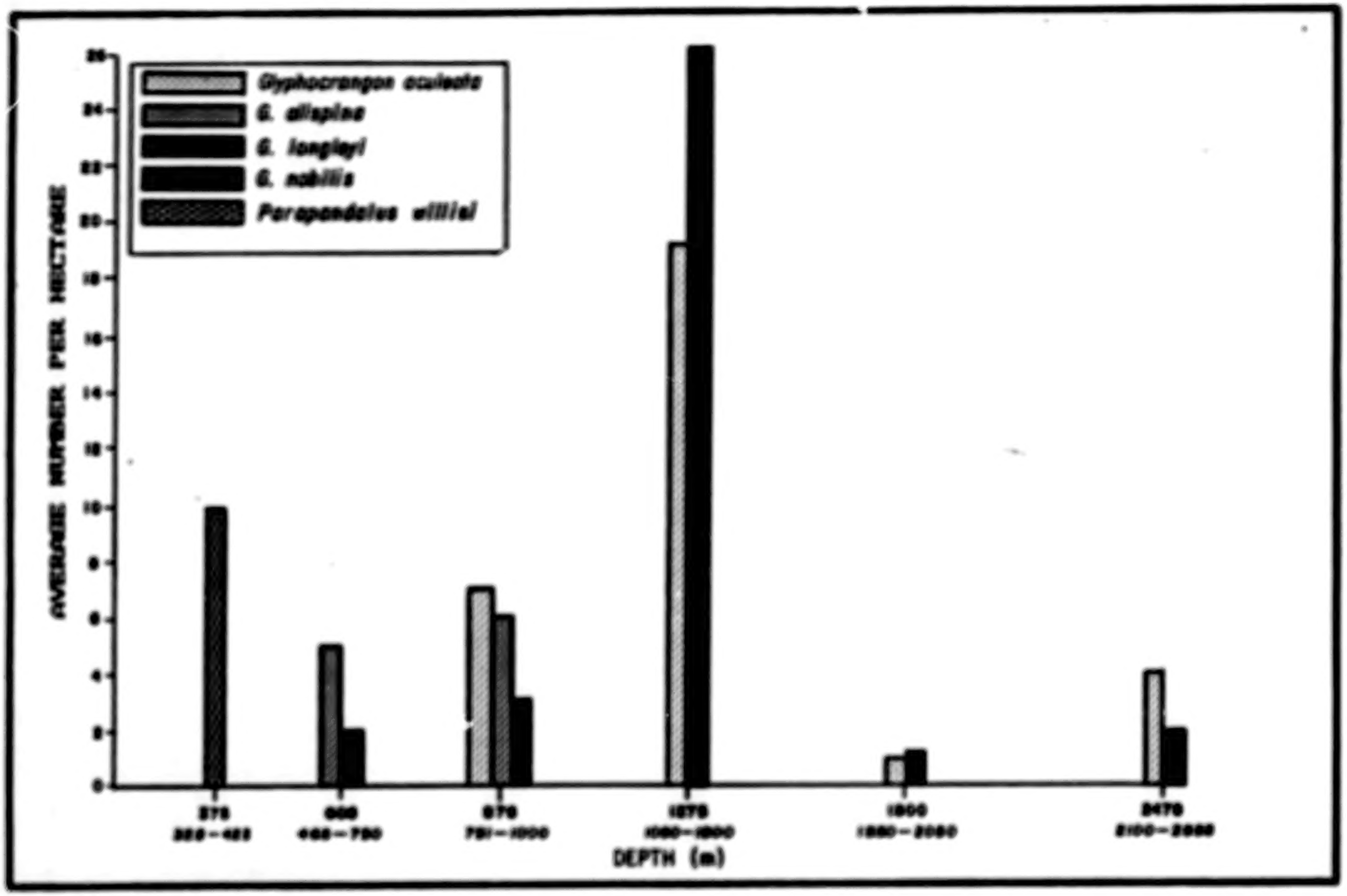

Figure 4-62. Average density (no./hectare) of four species of the genus Glyphocrangon and of Parapandalus willisi.

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at 10 of the 11 stations sampled in its depth range (Fig. 4-62). It appears to be somewhat more common on the Eastern Transect than on either the Central or Western Transect.

Anomura. The anomuran decapod crustaceans have five families that have species found on the northern slope of the Gulf of Mexico. The Paguridae, as hermit crabs, are represented by four genera, one of which, *Parapagurus*, has six species of which two are new to science. One of these, which is to be named *Parapagurus alaminos*, is being described by Dr. R. Lemaitre. This species has not been found east of DeSoto Canyon. The second family, Galatheidae, is represented by three genera, one of which, *Phylladiorhynchus* has an undescribedspecies. This genus, first found on Cruise V, is its first record in the Gulf. The other genera, *Munida* and *Munidopsis*, have been discussed in earlier reports. But Cruises IV and V collected a new species of *Munidopsis* (to be named "*parasobra*"), first records for the Gulf, for *Munida constricta* and *Munidopsis bahamensis*, and three very rare species: *Munidopsis spinoculata*, first described from the Gulf but with only two specimens having been collected since from the Caribbean Sea (Pequegnat and Pequegnat 1981), *Munidopsis* cf. *aries*, and *Munidopsis serratifrons*. The third family, Chirostylidae, has two species in the Gulf--*Uroptychus nitidus* and *Gastrophrychus spinifer*. The king crab family Lithodidae is represented by *Lithodes agassizi* in the Gulf, and the family Porcellanidae by *Porcellana sigsbeiana*.

Paguridae. Ten species of hermit crabs were collected from the slope of the northern Gulf. The two most abundant species in rank order are *Parapagurus pictus* and *Parapagurus pilosimanus* (Table 4-12). The third and fourth species in abundance, *Parapagurus alaminos* and *Pagurus rotundimanus*, yielded about a quarter of the individuals of the two leaders. *Parapagurus* is represented by five species (50% of all pagurid species). Interestingly two of the five species are represented by a single individual, so the two most abundant and the two least abundant species are siblings. Five *Parapagurus* species were taken at a total of 33 stations but only one of those was on the Eastern Transect (Station E4) while 16 were on the West Central and 16 on the Central Transects. Ninety of the 102 specimens of P. pictus were collected at eight stations on the West Central Transect of Cruise V. The depth ranges P. pictus extends from 342 to 775 m, and that of P. pilosimanus from about 603 to 1400 m.

Table 4-12. The most abundant anomurans on the slope of the northern Gulf of Mexico as determined by LGL and TerEco projects.

LGL				TerEco		
Species	Total Collected (All Stations)	Av. Density Per Hectare	Depth of Max. Pop.	Species	Total Collected	Depth of Max. Pop.
Parapagurus pictus	102	9	465	*P. pictus*	Not Reported	
Parapagurus pilosimanus	85	5	650	*P. pilosimanus*	18	600
Munida valida	1681	25	625	*M. valida*	114	650
Munida longipes	230	11	368	*M. longipes*	226	400
Munidopsis robusta	125	5	465	*M. robusta*	19	500
Munidopsis erinacea	101	4	680	*M. erinacea*	14	600
[illegible]	340	7	625	[illegible]	37	950
Lithodes agassizii	4	-	-	*L. agassizii*	8	1100
Porcellana sigsbeiana	3	-	-	*P. sigsbeiana*	83	200

According to Lemaitre (1986), *Parapagurus* (*Sympagurus*) *pictus* primarily lives symbiotically with a large actinian that serves as a shelter for the hermit crab. The actinian, *Sagartia*, forms a soft pseudoshell that covers the interior of the shelter. A similar relationship is observed between *Parapagurus pilosimanus* and zoanthids of the genus *Epizoanthus*.

Galatheidae. Three genera of galatheids (rock crabs) were collected. Two of them are polyspecific: *Munida* with nine species from the northern Gulf slope, and *Munidopsis* with 16 species. In general, species of *Munida* tend to occupy shallower depths than those of *Munidopsis*, but *Munida microphthalma* is an exception living at depths averaging 1400 m, whereas the more typical species, *Munida valida*, lives at depths averaging 685 m. Interestingly, the two most abundant species of *Munidopsis* occur at about the same depths as the leading species of *Munida* (Table 4-12).

The two most abundant species of *Munida* are *M. valida* and *M. longipes* (Table 4-12 and Fig. 4-59). *Munida valida* far outnumbers all other species in the genus; in fact, more specimens were collected of it than all other galatheids combined. Again, after the first two leaders, the maximum number of individuals in the remaining nine species is 11. The two rarest species of *Munida* are *M. evermanni*, taken only on the West Central Transect and *M. miles* taken at E1B on the shallow isobath. A more detailed treatment of the biology of *Munida valida* may be found in Section 4.3.4 of this report.

The two most abundant species of the genus *Munidopsis* are *M. robusta* and *M. erinaceus*. A more detailed treatment of the biology of *Munidopsis robusta* may be found in Section 4.3.4 of this report. Over one hundred individuals of both of these species were collected in the program, but an average of only 13 individuals of the remaining 14 species were collected--again illustrating the typical population drop among siblings. The isobathymetric sampling carried out on the Eastern Transect during Cruise IV collected *Munidopsis* species that had not been collected in the Gulf since being described, e.g., *M. ramahtaylorae* (Pequegnat and Pequegnat 1971). Five species occurred on the Central Transect and these also occurred on both East and West Transects (these were the population leaders); three species were restricted to the Eastern Transect, all were rare and distributed in the Caribbean; four species were found only on the West Central area; these also were rare and not collected previously in the northern Gulf; the remaining four species of the 16 were found on both East and West or West Central Transects but were not found on the Central Transect.

Eleven specimens of the third galatheid genus, *Phylladiorhynchus*, were collected at Station 6 in the West Central region at a depth of 663 m. This is the first record of the genus in the Gulf and it belongs to an undescribed species.

The fourth galatheid genus taken was *Eumunida* (*E. picta*). Its record at Station 6 in the West Central region is a first for the LGL study. Station WC-6 is near a seep area, which may account for both *Phylladiorhynchus* and *Eumunida* being taken there and at no other station.

Two species of chirostylid anomurans were collected in the program: *Uroptychus nitidus* is more common, being collected from all transects, as was *Gastroptychus spinifer* but in smaller numbers (Table 4-12). The habits of the latter are unknown, but *U. nitidus* is assumed to live only on the gorgonian coral *Chrysogorgia*, as is discussed later.

Five specimens of the king crab *Lithodes agassizi* were collected in the program and all were juveniles. The species is much more common in the western Gulf and the adults live at depths not frequently sampled in this program. Likewise the porcellanid crab *Porcellana sigsbeiana* is rare in the collection because it generally occurs at depths shallower than sampled in this program.

Macrura. The macruran decapods are represented in the LGL collection by 10 species in three families: Polychelidae, Nephropidae, and Scyllaridae (Table 4-13). *Stereomastis sculpta*, the most abundant of the macruran decapods in this study, is treated in more detail in Section 4.3.A of this report. Cruises IV and V produced some valuable new records and some major increases in numbers of individuals of species already in the collection. This was especially true of Cruise IV (Eastern Transect) where the nephropids *Acanthocaris caeca* and *Thaumastocheles zaleucus* were taken for the first time in the program. The taking of three specimens of *Thaumastocheles* is particularly significant because they are the first complete specimens seen by these authors. Moreover, the isobathymetric sampling of these two cruises more than doubled the number of individuals of every macruran species except *Scyllarus chacei*, which is a species that is more common at shallow depths in the western Gulf, and *Polycheles validus*, which inhabits much deeper waters than those sampled in this program.

Table 4-13. The most abundant macruran decapods on the slope of the northern Gulf of Mexico, as noted by the LGL and TerEco projects.

LGL				TerEco		
Species	Total Collected	Ave. Density Per Hectare	Depth (m) Max. Pop.	Species	Total Collected	Depth (m) Max. Pop.
[illegible]	732	11	1000	[illegible]	1409	1050
[illegible]	77	3	465	[illegible]	90	500
[illegible]	281	8	465	[illegible]	65	500

Brachyura. There are 28 species of brachyuran crabs now in the LGL collection, and of these, 11 were added by collections made during Cruises IV and V. Four of the 11 are worthy of special mention--two are undescribed species of the genus Cymonomus, and two are rare species; one individual of Robertsiella mystica found at Station WC-8 (479 m); and two individuals of Pyrhynchus thompsoni, one taken at Station E2D (628 m) and the other at Station WC-6 (near a seep area at 663 m). It should be noted also that Geryon fenneri was collected at Stations E1B (345 m) and E1C (350 m) on the Eastern Transect. This is likely the northernmost extension of its range.

The 28 brachyuran species are bathymetrically separable into three groups of unequal size: (1) those like Acanthocarpus alexandri, Bathynectes superba, Callinectes similis, and others which are common on the shelf but spill over onto the upper slope; (2) a larger group led by such species as Bathyplax typhla, Benthochascon schmitti, Rochinia crassa and Trichopeltarion nobile that live on the slope above the 1000 m isobath; and (3) the small group led by Geryon quinquedens, Homologenus rostratus, and a species or two not collected by the program that penetrate below 1000 m. This observation does not contradict the conclusion that brachyurans are denizens of the shelf and upper slope and are markers of high levels of organic production.

The five most abundant brachyurans on the slope of the northern Gulf are listed in Table 4-18

Table 4-14. The five most abundant brachyuran crabs collected by the LGL and TerEco projects.

	LGL				TerEco	
Species	Total Collected (All Stations)	Ave. Density Per Hectare	Depth (m): Max. Pop.	Species	Total Collected (All Stations)	Depth (m) Max. Pop.
Bathyplax typhla	2027	38	475	B. typhla	603	550
Benthochascon schmitti	1495	35	475	L. bairdii	262	300
Geryon quinquedens	124	2	1174	G. quinquedens	107	950
Lyreidus bairdii	98	6	342	B. schmitti	114	400
Pyromaia arachna	79	3	338	P. arachna	36	200

Note also the distribution of Bathyplax and Benthochascon in Figure 4-59. These latter two species are treated in more detail in Section 4.3.4 of this report.

Composition Abundance and Bathymetric Distribution of the Major Groups of Decapod Crustaceans. The penaeid shrimps are the only group of decapods that are most abundant in the shallowest depth interval shown in Figure 4-63 (328-423 m). The observed pattern is determined primarily by Penaeopsis serrata (see Fig. 4-59). The galatheids and brachyurans reach peak abundance at stations lying in the depth interval, 465-750 m. These patterns are determined primarily by Munida valida (galatheid) and Bathyplax typhla (brachyuran), as shown in Figure 4-59. The caridea have a secondary peak at stations in this depth interval, but the major peak of abundance is found at stations in the 1050-1500 m depth interval. It is clear from an examination of Figure 4-59 that this bimodal pattern is determined by Nematocarcinus rotundus. The macruran curve follows the abundance curve of the flatbacked lobsterette, Stereomastis sculpta.

4.3.3.6 Pogonophora/Vestimentifera

Two species of pogonophorans, viz., Galathealinum n. sp. (464 m) and Lamellibrachia sp. (464 m) were taken by the trawl on the West-Central Transect at Station WC7 only.

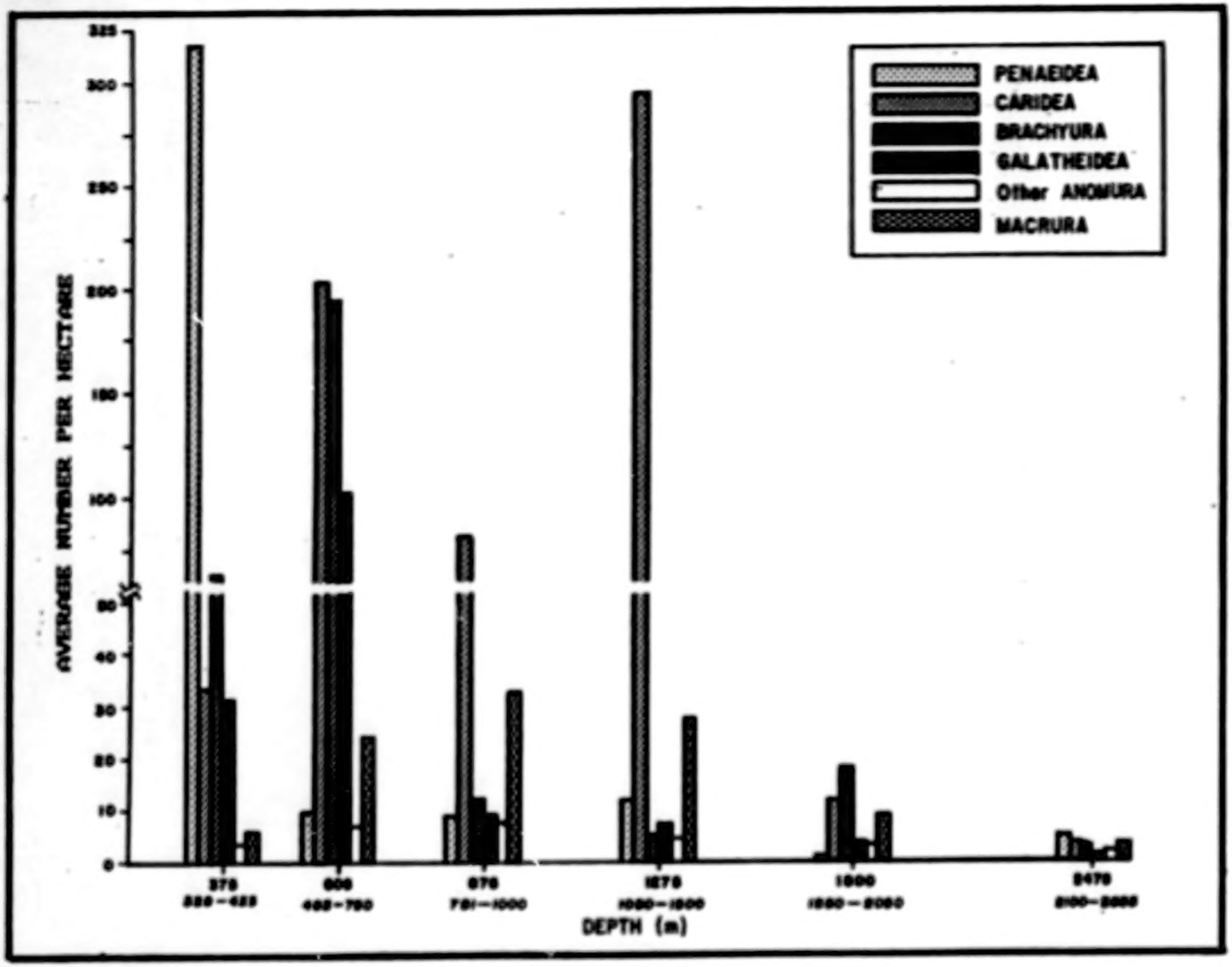

Figure 4-63. Relative abundance (ave. no./station) of the major groups of decapods.

4.3.3.7 Brachiopoda

Only two species of brachiopods were taken in the trawl, both in small numbers *Ecnomiosa gerda* was taken at a single station on the Central Transect (964 m), *Platidia anomioides* was taken at two stations on the West-Central Transect at about 700 m depth. The latter is a widespread species that is not normally common to U.S. waters.

4.3.3.8 Echinodermata

One hundred twenty-six species of megafaunal echinoderms were collected by trawling from the three transects. Forty-two of these species were collected for the first time during Cruises IV and V. These were distributed among the echinoderm classes, as follows: 13 asteroids, 15 ophiuroids, 5 echinoids, 5 holothuroids, and 4 crinoids. Overall the ophiuroids and asteroids account for about 70% of all the echinoderm species collected in the project (Table 4-15 and Fig. 4-64).

Table 4-15. Total numbers of the five classes of megafaunal echinoderms.

Class	No. of Species	Percent of all Echinoderm Species
Ophiuroidea	45	36
Asteroidea	41	32
Holothuroidea	21	17
Echinoidea	13	10
Crinoidea	6	5
	126	100

Asteroidea

A total of 41 species of asteroids was collected during the five cruises. Among the 13 species that were collected for the first time during Cruises IV and V were the rare genus *Caymanostella* sp. and the

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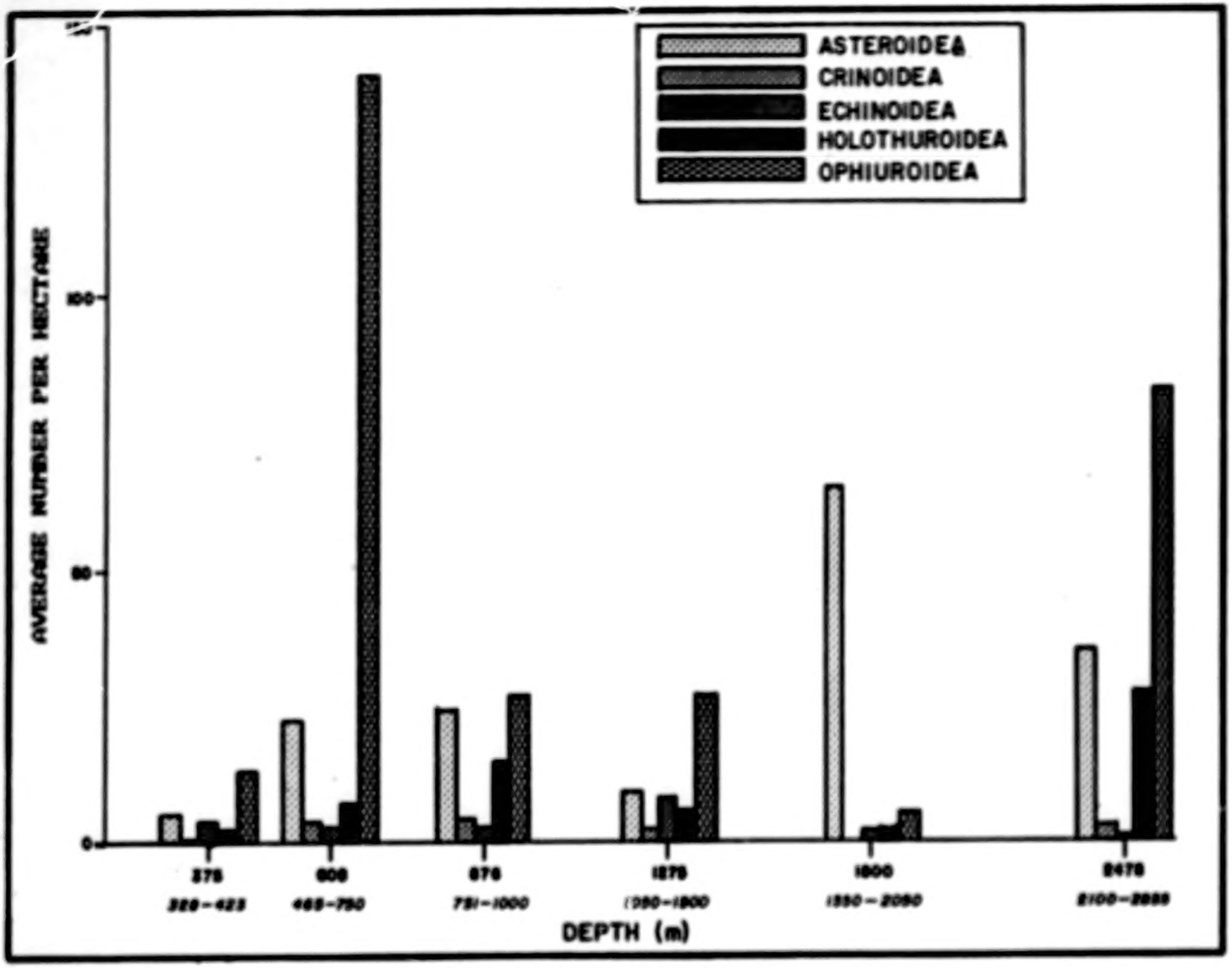


Figure 4-64. Total individuals collected of the five echinoderm classes.

species *Circeaster americanus*, as well as *Odontaster setosus* and *Sclerasterias contorta*.

The five most abundant asteroids are shown in Table 4-16 of which the leader is considered to be *Nymphaster arenatus* because it was taken at such a large number of stations.

Table 4-16. Abundance of the five most abundant asteroid species collected from the three major transects.

Species	Total Collected	No. of Stations	Depth Range on Transects
Nymphaster arenatus	45	24	375-1800
Pectinaster gracilis	63	13	465- 750
Persephonaster echinulatus	81	13	465- 750
Plinthaster dentatus	25	16	465-2100
Plutonaster intermedius	41	9	876-2100

As shown in Figure 4-64, the abundance of asteroids in this project follows an irregular trend of increase from 328 m to around 1800 m, after which there appears to be a reversal of the trend. In part the latter reduction results from the fact that the project's sampling effort did not effectively cover the lower slope where an abyssal assemblage having such species as *Dytaster insignis*, *Benthopecten simplex*, *Ampheraster alaminos*, and *Litonotaster intermedius* is to be found.

Although 61 species of starfishes were identified in the TerEco project (20 more than LGL), it is interesting to note that exactly 20 of the 61 reach maximum populations either shallower or deeper than sampled in the present project.

Ophiuroidea

Forty-five species of ophiuroids were collected by trawling in this project. This compares with 30 species of ophiuroids collected during the first three cruises and 43 species listed in the TerEco study. The 15 "new" species of Cruises IV and V were distributed unequally among the transects: eight were taken only on the West Central Transect, four only on the Eastern Transect, and three on both. The majority (9 of the 15) were represented by a single individual and that those three species found on both transects accounted for a disproportionate one-third of the total individuals taken. The six most abundant ophiuroids in the project are listed in Table 4-17.

Table 4-17. The six most abundant ophiuroid species collected from the three major transects.

Species	Total Collected	No. of Stations Where Collected	Depth Range on Transects
Ophiernus adspersus	986	19	423- 805
Bathypectinura heros	211	18	615-2400
Ophiochiton grandis	175	17	420- 850
Ophiolipus agassizii	147	16	329- 625
Amphiophiura sculptilis	116	11	750-1440
Amphilepis cf. *ingolfiensis*	492	3	750-2855

Both *Ophiernus adspersus* and *Bathypectinura heros* were among the five most abundant brittle stars in the TerEco study.

The abundance of ophiuroids has a marked bimodal characteristic with one peak around 600 m, which is probably determined primarily by *Ophiernus adspersus*, and the other much deeper peak (Fig. 4-64) was probably caused by species of the genus *Amphilepis*.

Echinoidea

Thirteen species of sea-urchins were collected from the three major transects. The echinoid species were most common on the Central Transect, where 8 of the 13 species were found (six found only on that transect). Three species were found only on the Eastern Transect, two species were restricted to the West Central region, and one species each occurred on the Central and Eastern or on the Central and Western Transects.

The most abundant echinoid species in the present collection is *Plesiodiadema antillarum* followed by *Homolampas fragilis* and *Brissopsis alta* (Table 4-18).

Table 4-18. Total numbers of the five most abundant sea-urchins trawled from the major transects.

Species	Total Collected	No. of Stations	Depth Range (m)
Plesiodiadema antillarum	70	6	750-1500
Homolampas fragilis	17	6	465- 750
Brissopsis alta	19	3	328- 750
Aceste bellidifera	7	3	465- 750
Brissopsis sp.	13	1	328- 423

The totals shown in Table 4-18 are small, reflecting the fact that the project's sampling depths were too deep to get typical numbers of *Brissopsis* and not extensive enough in deep waters to get representative numbers of either *Plesiodiadema* or *Phormosoma placenta placenta*. Also, the low numbers of echinoids (Fig. 4-64) is related in part to the fact that some species like *Plesiodiadema antillarum* and *Phormosa placenta* occur in isolated "herds", as determined by benthic photography.

Holothuroidea

Twenty-one species of sea cucumbers were collected by trawling in this project. These species were distributed very unequally among the transects--18 of the 21 species were found on the Central Transect (10 were found only on this transect); nine species were collected from the Eastern Transect (only one species was restricted to this transect); nine species were collected from the Western or West Central Transect (only one species was restricted to this transect); and six species were found on all transects. Three of the four most abundant species were found on all transects and all four were found on the Central Transect (Table 4-19). The flow from the Mississippi River moves westward across this transect where it deposits some of its load of organic matter. This is important to the sea cucumbers found there in that all are thought to be deposit feeders.

Table 4-19. The four most abundant holothuroid species collected from the three major transects.

Species	Total Collected	No. of Stations Where Collected	Depth Range on Transects
Mesothuria lactea	184	18	603-1170
Molpadia barbouri	44	15	840-2400
Molpadia musculus	38	9	838-2400
Benthodytes typica	101	3	2050-2500

As shown in Table 4-19 and Figure 4-64 the sea cucumbers tend to have both shallow and deep assemblages.

Crinoidea

Six taxa of crinoids (four definitive species) were collected in the project, four being added for the first time during Cruises IV and V. The latter four, however, were found only in very small numbers; hence the two most abundant species are the same as reported for Cruises I to III.

The most abundant now is Democrinus brevis followed by Atelecrinus balanoides (Table 4-20).

Table 4-20. Complete inventory of crinoids collected in the project.

Species	Total No. Collected	No. of Stations Where Found	Depth Range on Transects
Democrinus brevis	280	17	620-2400
Ateleocrinus balanoides	67	15	620-1200
Caryometra alope	7	3	522- 663
Caryometra lisa	11	2	600- 775
Caryometra sp.	1 juv.	1	740
Comatulida	1	1	615

4.3.3.9 *Ascidiacea (Chordata)*

Only one individual of one species of sea squirt was collected in the trawl. *Bathystyeloides enderbyanus* was taken at a depth of 2400 m on the Central Transect.

4.3.4 DECAPOD SPECIES ACCOUNTS

4.3.4.1 *Bathyplax typhla* (A. Milne Edwards, 1880 Family Goneplacidae)

Distribution

The reaper crab, *Bathyplax typhla*, is one of the most abundant deep-sea brachyurans in the Gulf of Mexico (Pequegnat and Chace 1970). It has been reported from North Carolina to Brazil, and throughout the Gulf of Mexico on the upper continental slope (Pequegnat et al. 1971), in depths of 402 to 878 m (Powers 1977). In the Straits of Florida, it is restricted to water colder than 10°C, and deeper than 315 m (Soto 1985). It has usually been found over muddy substrates (Soto 1985, Powers 1977), although Powers indicated that it also has been taken from "coral bottoms." Powers was probably referring to calcareous rubble, foraminiferans, or sand, rather than reef corals, which would not be present at the depths indicated.

During the *Alaminos* cruises, *Bathyplax typhla* was the numerical dominant in the deep Gulf, having been collected by benthic skimmer in depths from 512 to 860 m at densities ranging from 16 to 135 per ha, with the highest density in Pequegnat's (1983) Archibenthal Zone, between 658 and 860 m. Pequegnat listed the depth of peak population density for *Bathyplax typhla* as being 550 m. Specimens apparently contaminated by petroleum from natural oil seeps have been described as common by Pequegnat and Chace (1970).

During this program, *Bathyplax typhla* was collected on all five cruises, at depths ranging from 366 to 1,438 m (Fig. 4-65). Specimens were taken on the Central Transect from 474 to 1,438 m; on the Eastern Transect from 366 to 1,170 m; on the Western Transect from 654 to 828 m; and on the West Central Transect from 464 to 751 m.

Measurements

Bathyplax typhla males collected during the *Alaminos* cruises reached 28 mm (carapace width); females reached 25 mm, with ovigerous specimens from 16 to 22 mm in width taken in August, November, and December.

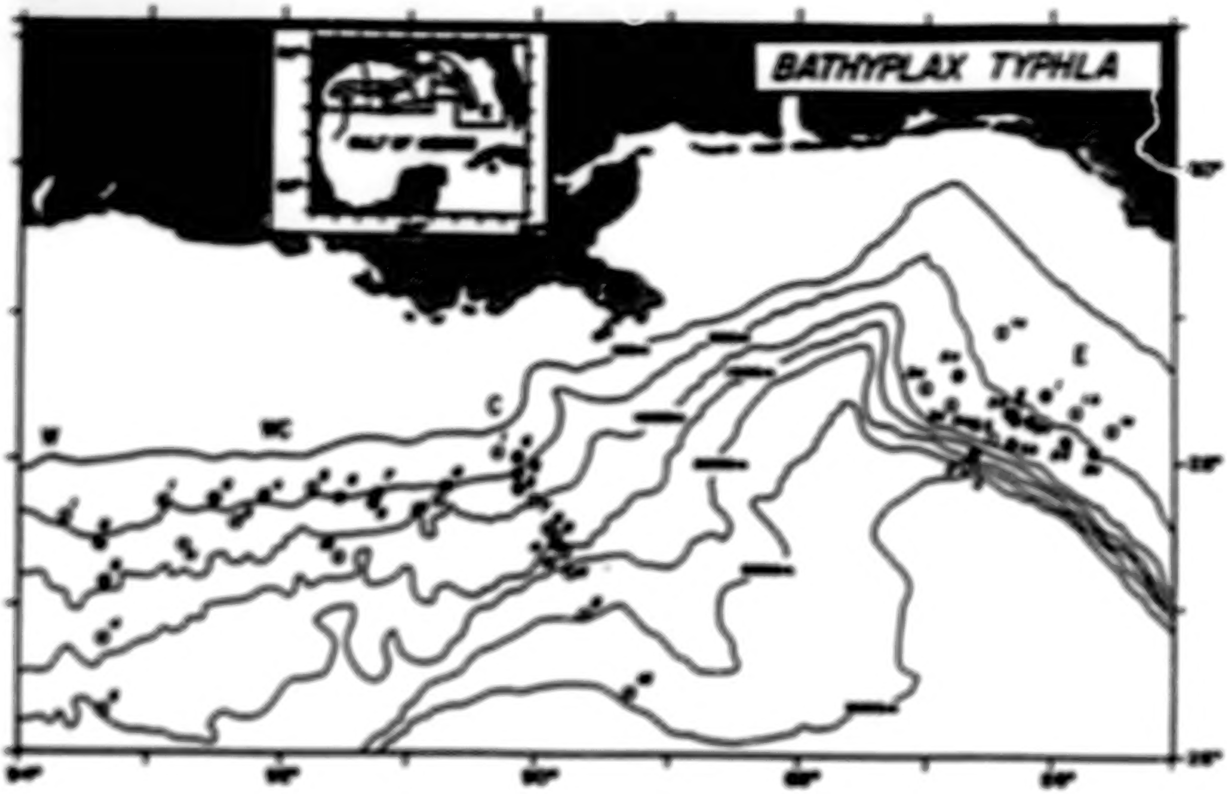


Figure 4-65. Locations where Bathyplax typhla were collected (closed circles).

Crabs taken during this program had a unimodal, bell-shaped curve of size frequencies (Fig. 4-66A) total of 581 individuals was measured. They ranged between 11 and 32 mm in width, and averaged 20.6 mm. Both males and females had similar widths (Fig. 4-67). Ovigerous females averaged 22.9 mm, within a range of 18 to 28 mm. About one-fifth of the females collected (49 out of 273) were ovigerous. Non-ovigerous females ranged from 10 to 31 mm in width, with a mean of 20.3 mm. Males averaged 19.3 mm wide, within a range of 11 to 32 mm. The size distribution of individuals remained very similar from cruise to cruise, without apparent cohorts or age class peaks or seasonal trends (Fig. 4-68). There was a positive linear correlation (r = 0.95) between the logs of width and wet weight (Fig. 4-66B) for all specimens together. Weights ranged from 0.3 to 11.9 g, with a mean of 2.9 g.

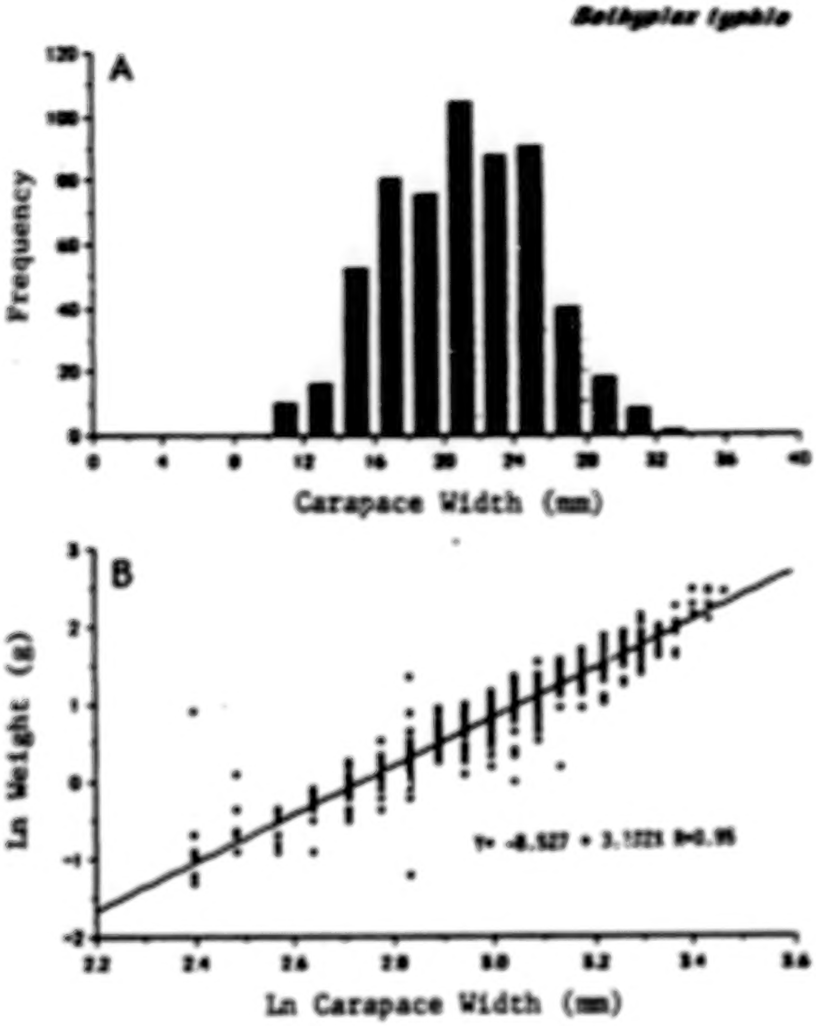


Figure 4-66. Frequency histogram (A) and size-weight relationship (B) for carapace widths of Bathyplax typhla (all stations pooled).

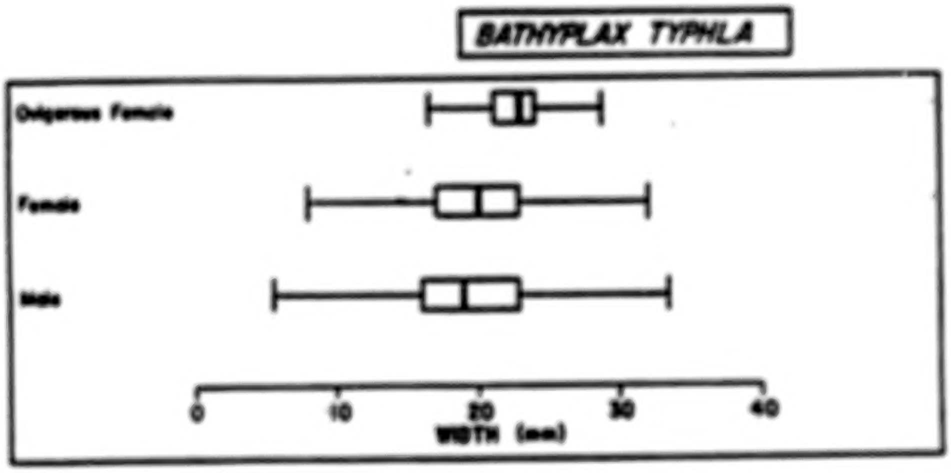
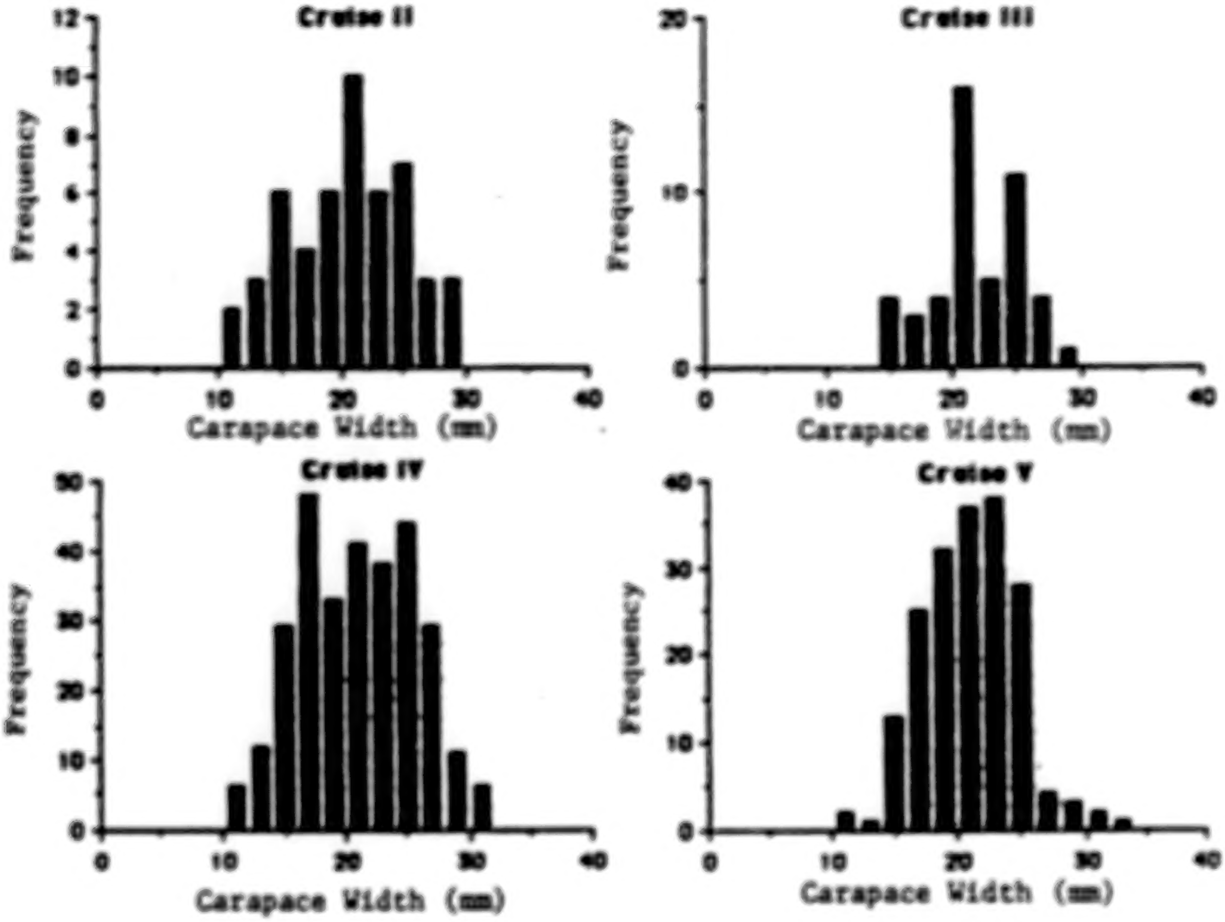


Figure 4-67. Median size (dark vertical bars), 25th and 75th percentiles (boxes), and approximate confidence intervals (whiskers) on carapace widths of Bathyplax typhla (small squares mark outliers).

Bathyplax typhla


Cruise II

Cruise III

Cruise IV

Cruise V

Figure 4-68. Frequency histograms for carapace widths of Bathyplax typhla from individual cruises.

4.3.4.2 *Benthesicymus bartletti* (Smith, 1882 Family Penaeidae)

Distribution

Benthesicymus bartletti, Bartlett's short-horned prawn, has been collected on both sides of the Atlantic Ocean, in the Pacific, and in the Caribbean and Gulf of Mexico, although there is some question about its presence in the eastern Indo-Pacific (Crosnier 1978). It appears to be exclusively benthic, seldom if ever venturing much above the bottom (Wenner 1980, Pequegnat and Chace 1970). Its depth range in the Caribbean and the Gulf *Alaminos* collections was between 731 and 1,773 m. Some specimens may have been taken by the *Blake* at 1,934 and 2,866 m, although Pequegnat and Chace (1970) questioned the authenticity of the deeper record. Pequegnat (1983) indicated a depth range of 700 to 2250 m in the Gulf, with a population peak in the Upper Abyssal Zone near 1050 m. Wenner (1980) noted an early record of *Benthesicymus bartletti* from 5,777 m, but her collections on the US Atlantic continental slope produced relatively few specimens shallower than 1,000 m, or deeper than 2000 m.

During this program, *Benthesicymus bartletti* was collected on all five cruises, at depths from 746 to 2,074 m m (Fig. 4-69). Specimens were taken on the Central Transect from 802 to 2,074 m; on the Eastern Transect from 834 to 1,170 m; on the Western Transect from 828 m to 1,413 m; and on the West Central Transect from 746 to 1,206 m.

Measurements

Benthesicymus bartletti collected on the continental slope of the Middle Atlantic Bight by Wenner (1970) ranged between about 7 and 30 mm in carapace length (from the posterior margin of carapace to the base of the rostrum). Males were slightly smaller than females (means = 19.9 mm and 21.5 mm, respectively). Females over 20 mm long with ripe gonads were present at various times of year, but the sample size was too small to determine if breeding took place seasonally or throughout the year.

In this study, 95 measured specimens of *Benthesicymus bartletti* were from 6 to 27 mm in carapace length, with a mean of 19.4 mm. The female size range overlapped the male size range at both ends (Fig. 4-70).

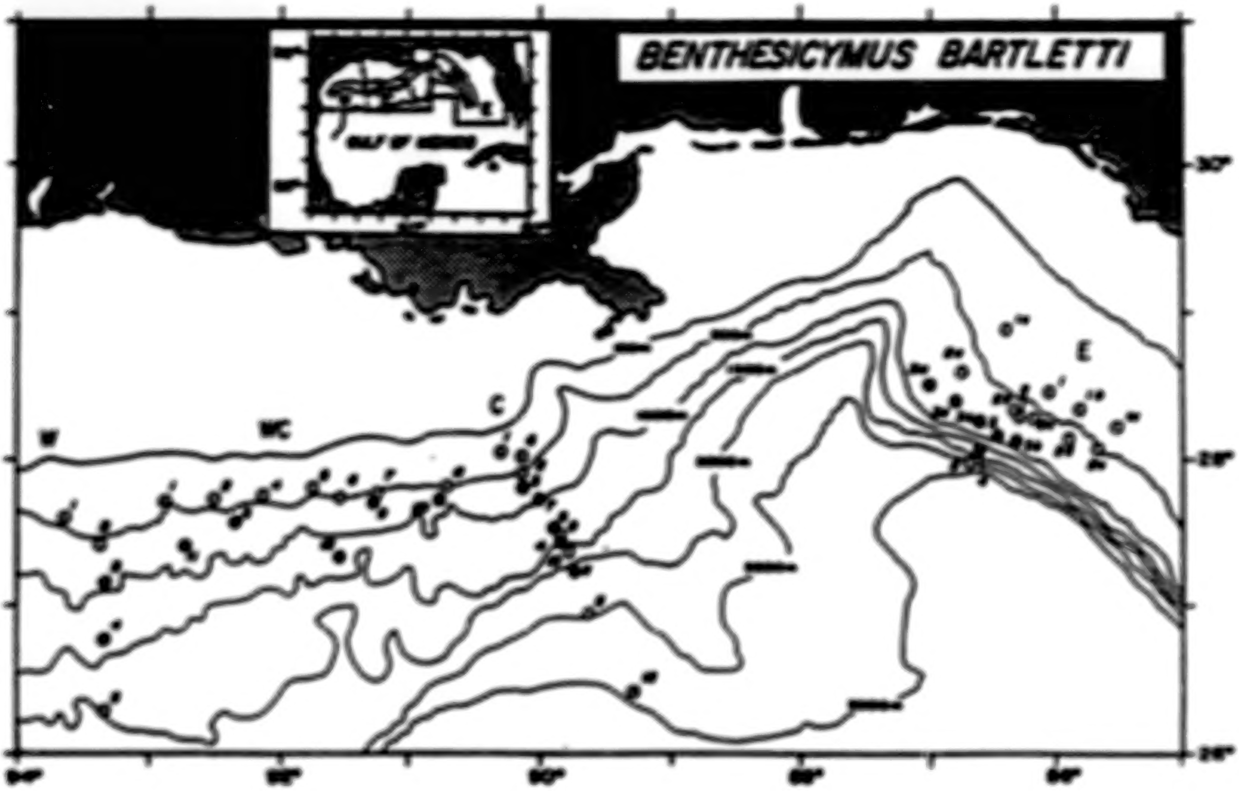


Figure 4-69. Locations where Benthesicymus barteletti were collected (closed circles).

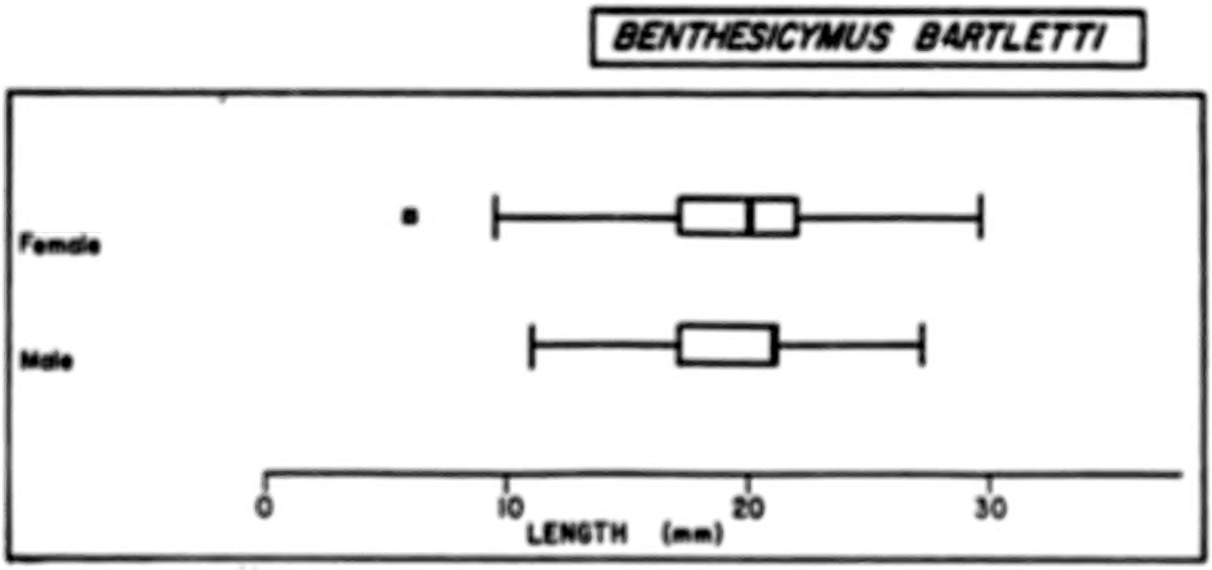


Figure 4-70. Median size (dark vertical bars), 25th and 75th percentiles (boxes), and approximate confidence intervals (whiskers) on carapace lengths of Benthesicymus barteletti (small squares mark outliers.

Males were between 12 and 22 mm long, with a mean of 19.3 mm. Females averaged 19.4 in length, within a range of 6 to 27 mm. The overall size frequency distribution showed no obvious cohorts (Fig. 4-71A), but sample size on each cruise was inadequate to detect seasonal trends (Fig. 4-72). There was a positive linear relationship ($r = 0.97$) between the logs of weight and carapace length (Fig. 4-71B). Weights ranged from 0.3 to 8.0 grams, with a mean of 3.4 g.

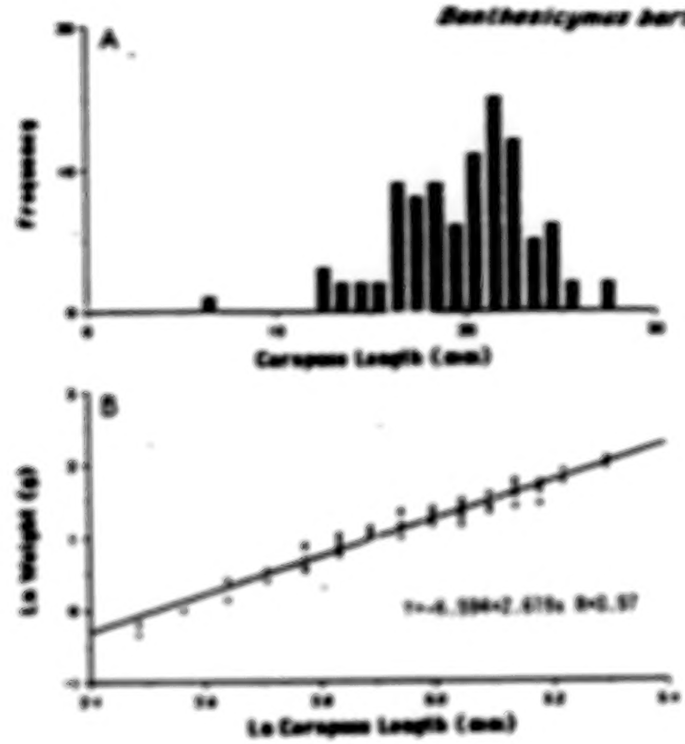


Figure 4-71. Frequency histogram (A) and size-weight relationship (B) for carapace lengths of Benthesicymus barteletti (all stations pooled).

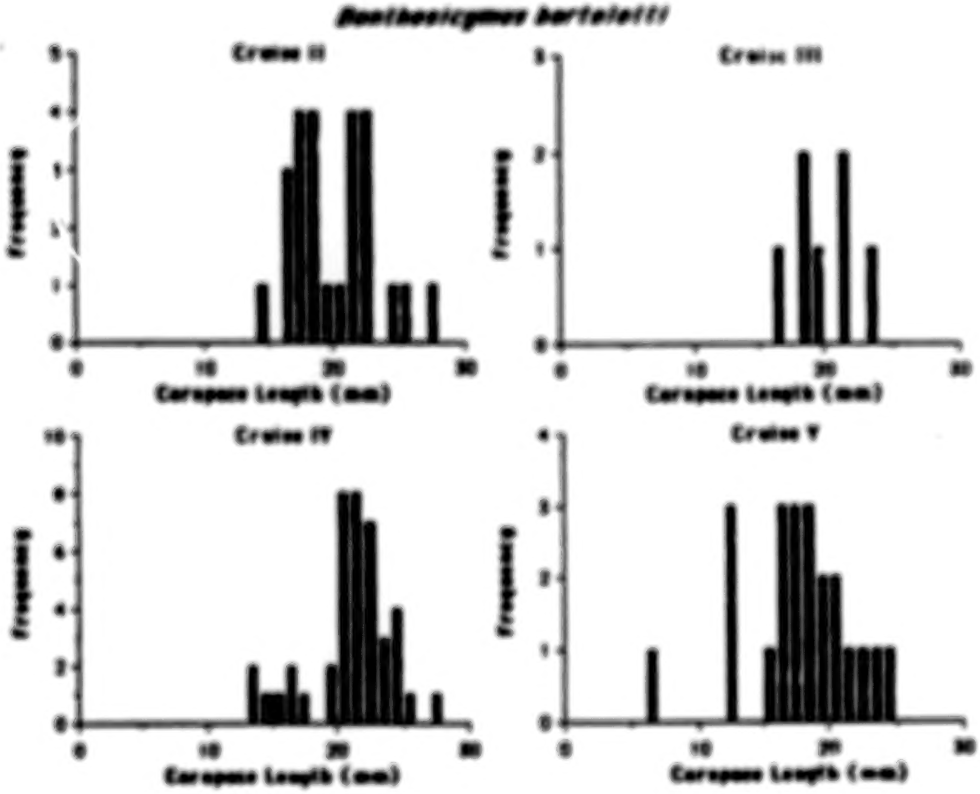


Figure 4-72. Frequency histograms for carapace lengths of Benthesicymus barteletti from individual cruises.

4.3.4.3 Benthochascon schmitti (Rathbun, 1931 Family Portunidae)

Distribution

Schmitt's benthic portunid, Benthochascon schmitti, was thought to be an endemic species in the Gulf of Mexico (Pequegnat and Chace 1970, Pequegnat et al. 1971). However, there is a single record off southern New England (Wigley and Messersmith 1976, from Powers 1977), and many records from the Straits of Florida in water from 183 to 366 m deep (Soto 1985). Within the Gulf, it has been collected from the Dry Tortugas to the northern Gulf, within a depth range of 200 to 650 m. Its maximum population density occurs near 400 m (Pequegnat 1983). It thus inhabits the Shelf/Slope Transition and Archibenthal zones defined by Pequegnat (1983). Densities reported by Pequegnat and Chace (1970) were from 2 to 40 individuals per hectare. Benthochascon prefers mud and silt-clay substrates (Powers 1977).

During this program, Benthochascon schmitti was captured on all five cruises, at depths clustering around the 400 m isobath and extending from 329 to 840 m (Fig. 4-73). Collections at 751 m and 840 m represent substantial depth range extensions for this species. Specimens were taken on the Central Transect from 239 to 632 m; on the Eastern Transect from 366 to 840 m; on the Western Transect at 342 m; and on the West Central Transect from 368 to 751 m.

Measurements

Immature Benthochascon males and females were collected from March through October during the Alaminos cruises (Pequegnat and Chace 1970, Pequegnat 1983), although their size was not reported.

During this program, 305 measured specimens were from 12 to 86 mm in carapace width. The size range of females was similar to that of the males (Fig. 4-74). There was only one ovigerous female collected, 59 mm wide. Non-ovigerous females were from 12 to 65 mm wide, with a mean of 40.4 mm. Mean width for males was 26.9 mm, within a range of 11 to 86 mm.

Two peaks were evident in the overall size frequency distribution (Fig. 4-75A), suggesting the seasonal passage of cohorts or age classes,

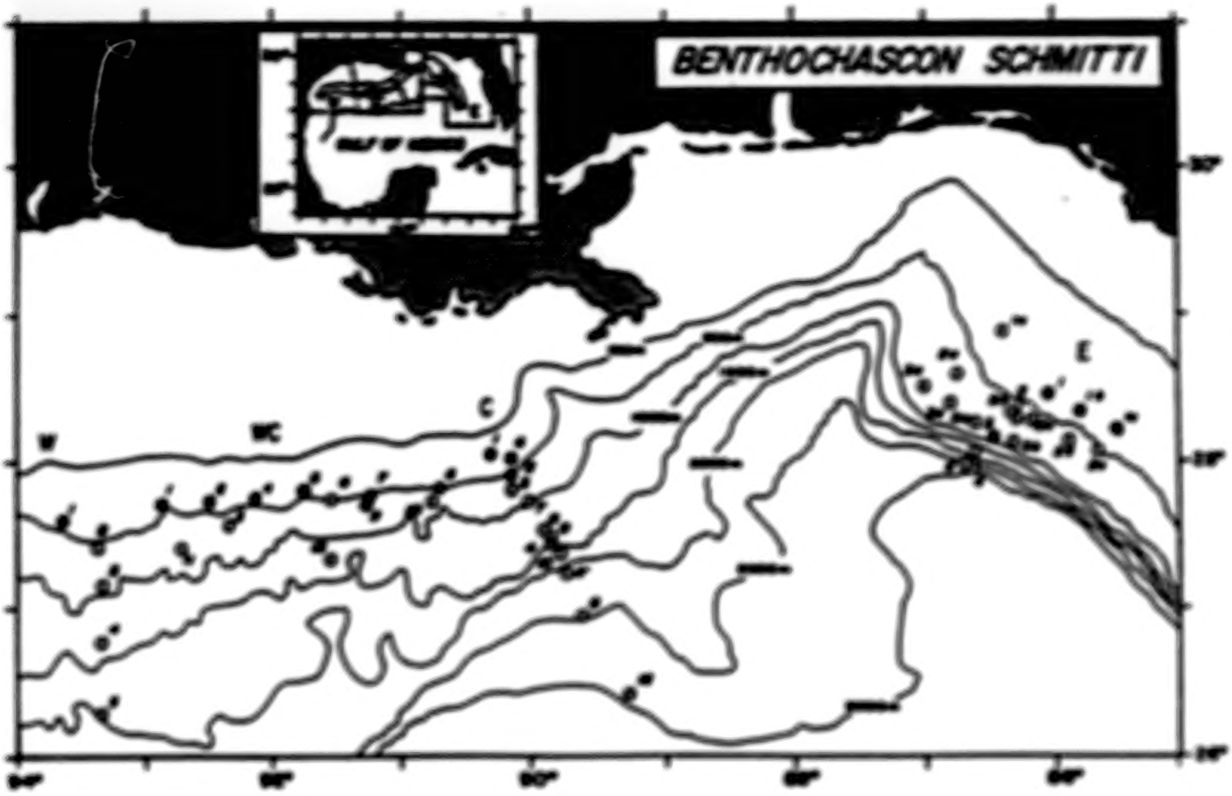


Figure 4-73. Locations where Benthochascon schmitti were collected (closed circles).

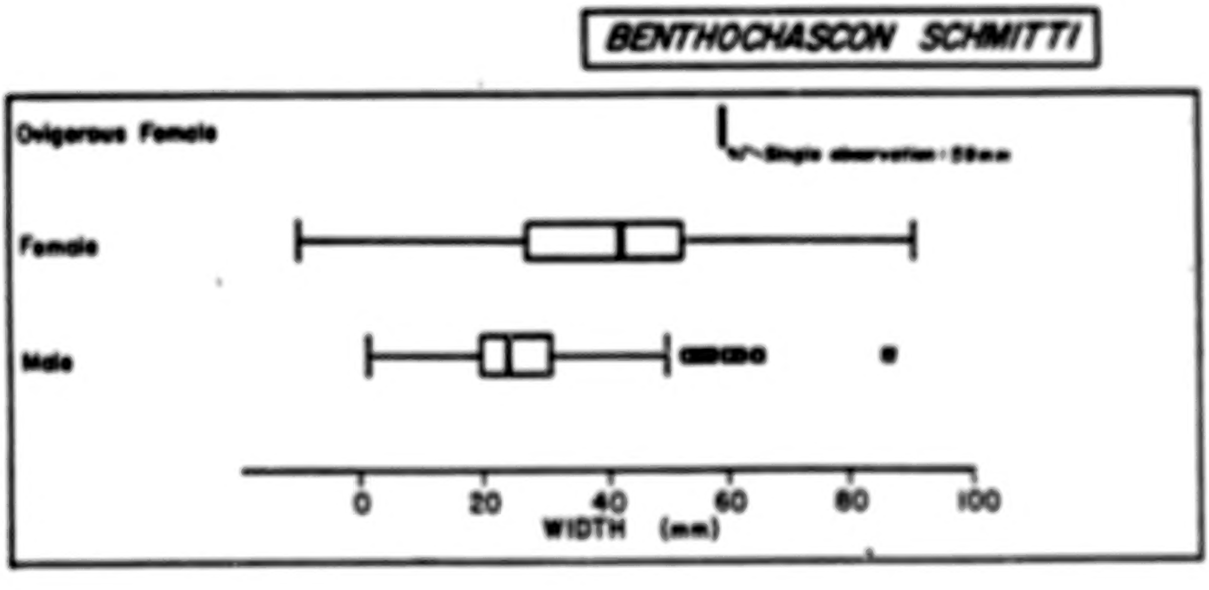


Figure 4-74. Median size (dark vertical bars), 25th and 75th percentiles (boxes), and approximate confidence intervals (whiskers) on carapace widths of Benthochascon schmitti (small squares mark outliers).

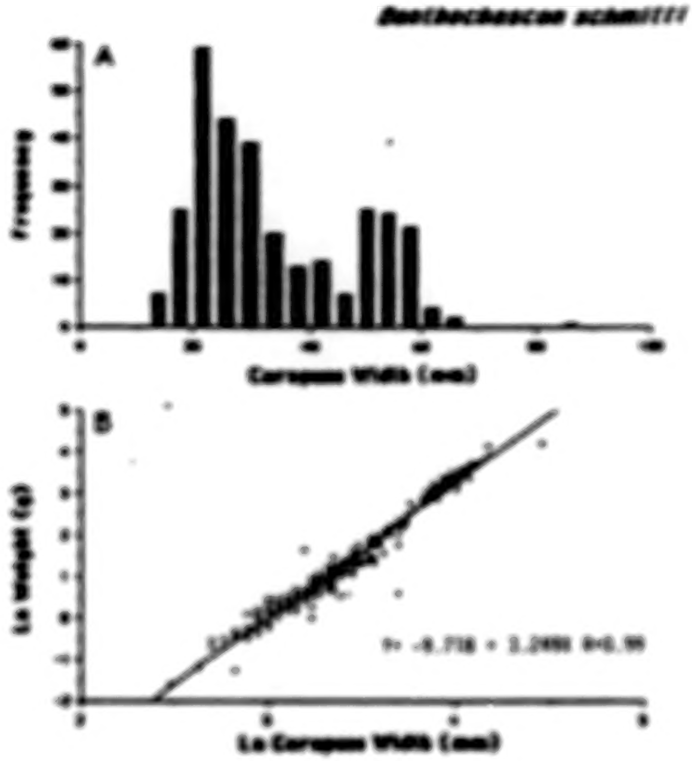


Figure 4-75. Frequency histogram (A) and size-weight relationship (B) for carapace widths of Benthochascon schmitti (all stations pooled).

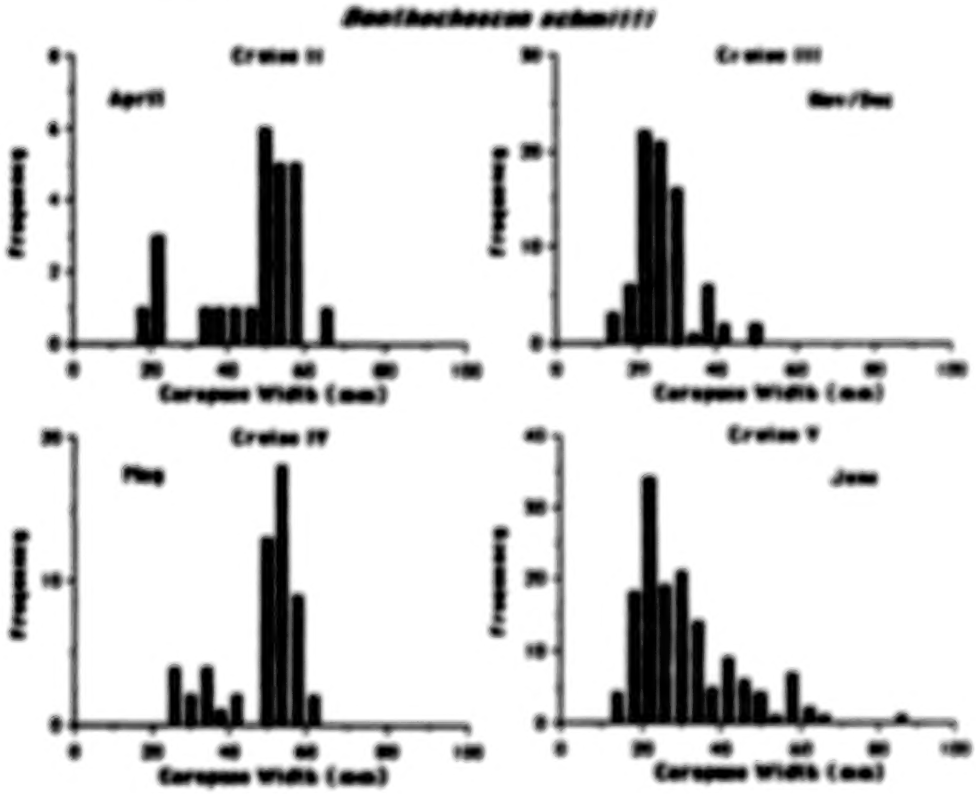


Figure 4-76. Frequency histograms for carapace widths of Benthochascon schmitti from individual cruises.

or size-specific sex differences. Specimens taken on Cruises II and IV (April 1984 and May 1985) were larger than those collected on Cruises III and V (November/December 1984 and June 1985) (Fig. 4-76). Most individuals collected during Cruise III and V collections were between 20 and 40 mm wide, whereas Cruise II and IV collections were dominated by specimens from 40 to 60 mm in width.

There was a positive linear correlation ($r = 0.99$) between the log of specimen width and weight (Fig. 4-75B) for all specimens together. Weights ranged from 0.2 to 65.7 g, with a mean of 9.9 g. Larger specimens were disproportionately heavy, perhaps as a result of increasing calcification and decreasing molt frequency, as is common in other crustaceans.

One possible explanation for the differences between cruises would be the ability of larger specimens (e.g. those greater than 60 mm in width) to escape capture, proposed by Pequegnat and Chace (1970). This factor combined with an annual spring recruitment, could be responsible for an apparent fall disappearance of large size classes from collections. Large specimens--similar to those taken in the spring on Cruises II and IV--might have grown enough by summer to avoid capture during Cruises III and V. Individuals that were newly recruited in the spring might have been too small to be taken on Cruises II and IV, but could have been large enough to be vulnerable to the net by summer.

However, the presence of many small individuals in the November/December sample (Cruise III) is problematical, and implies more than one annual peak of recruitment. This scheme is presented only as a hypothesis for further examination, and alternative hypotheses (e.g. heavy adult mortality, emigration, seasonal differences among transects, or segregation by sex or size class) are also plausible but have not yet been examined.

4.3.4.4 *Glyphocrangon aculeata* (A. Milne Edwards, 1881 Family Glyphocrangonidae)

Distribution

The sharp-spined armored shrimp, *Glyphocrangon aculeata*, is a widely distributed deep-sea caridean, ranging from the western Atlantic (Delaware to Brazil), the Straits of Florida, the Gulf of Mexico, and the southern Caribbean (Pequegnat and Chace 1970). Pequegnat et al. (1971) noted that it was far more abundant in the western Gulf than the eastern Gulf, and typical of the upper continental slope, within the Upper Abyssal Zone (Pequegnat 1983). It has been reported from depths of 732 to 1,767 m, with an apparent abundance maximum around 1150 m (Pequegnat 1983, Holthuis 1971). It has been taken over various bottom types, including gray ooze, yellow ooze, *Globigerina* ooze, mud of various colors, clay, fine sand with black specks, forams, etc.

Glyphocrangon aculeata was collected during this program on all five cruises, at depths ranging from 751 to 2,857 m (Fig. 4-77). The latter represents a depth extension of almost 1,100 m over published reports. Specimens were taken on the Central transect from 964 to 1,510 m; on the Eastern Transect from 812 to 2,857 m; on the Western Transect at 828 m; and on the West Central Transect from 751 to 1,206 m.

Measurements

Specimens of *Glyphocrangon aculeata* taken during the *Alaminos* cruises were between 5 and 33 mm in carapace length, excluding the rostrum (Pequegnat and Chace 1970). Ovigerous females were collected in August and November, and were at least 20 mm long. The *Alaminos* specimens from the Gulf of Mexico were smaller than many that have been collected in the Atlantic. Holthuis (1971) examined a large number of specimens from various locations, and measured ovigerous females at 36 to 49 mm carapace length, including the rostrum. The largest male Holthuis measured was 38 mm in carapace length, including the rostrum.

During this program, 268 measured specimens of *Glyphocrangon aculeata* were between 5 and 31 mm in carapace length, excluding the rostrum (Fig.

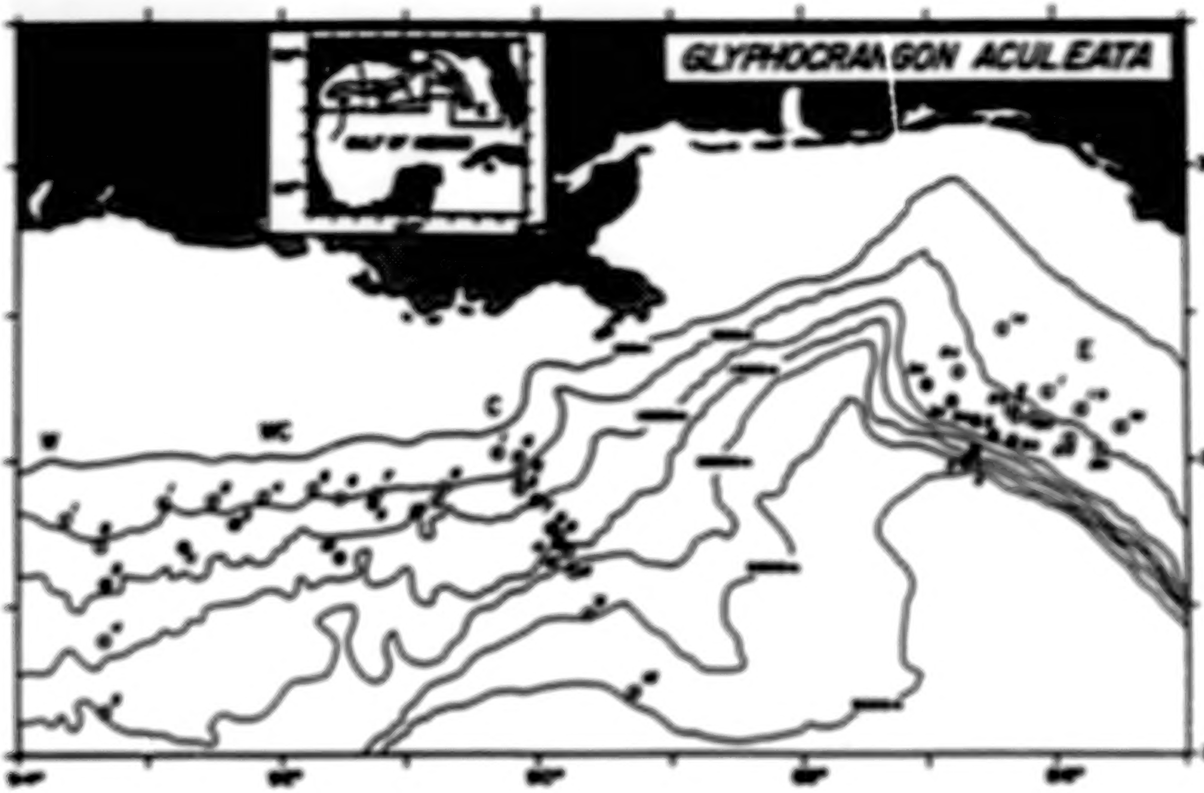


Figure 4-77. Locations where Glyphocrangon aculeata were collected (closed circles).

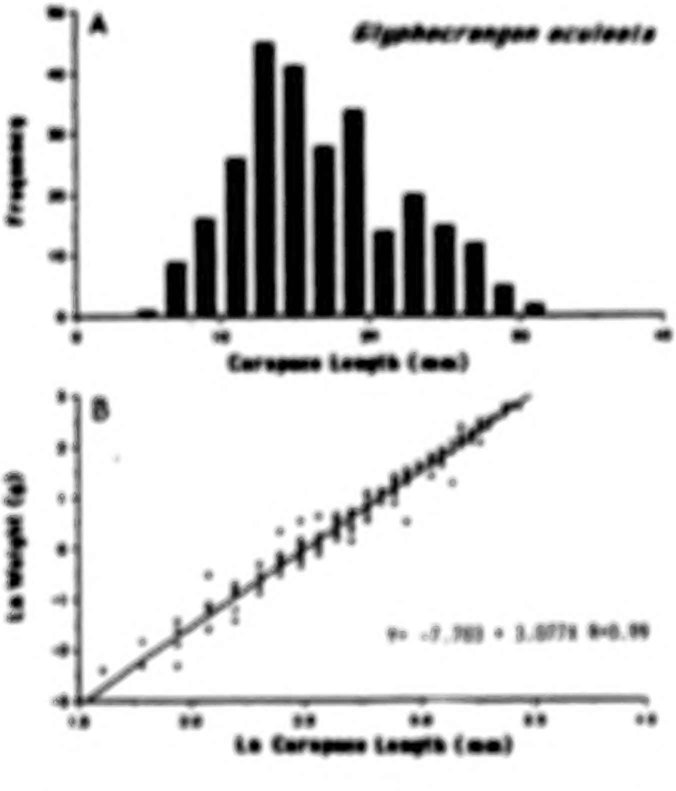


Figure 4-78. Frequency histogram (A) and size-weight relationship (B) for carapace lengths of Glyphocrangon aculeata (all stations pooled).

4-78A). There were no obvious individual peaks representing separate cohorts. Female lengths overlapped the male length range at both ends, and ovigerous females were, on the average, considerably larger than were non-ovigerous females or males (Fig. 4-79). About a fourth of the females collected (33 out of 126) were ovigerous. Mean length for ovigerous females was 24.8 mm, within a range of 14 to 30 mm. Mean length for non-ovigerous females was 17.7 mm, within a range of 9 to 31 mm. Males were between 10 and 22 mm long, with a mean of 15.9 mm. No clear seasonal differences in size were noted (Fig. 4-80). There was a positive linear correlation ($r = 0.99$) between the logs of weight and carapace length (Fig. 4-78B) for all specimens together. Weights ranged from 0.9 to 16.7 g, with a mean of 3.4 g.

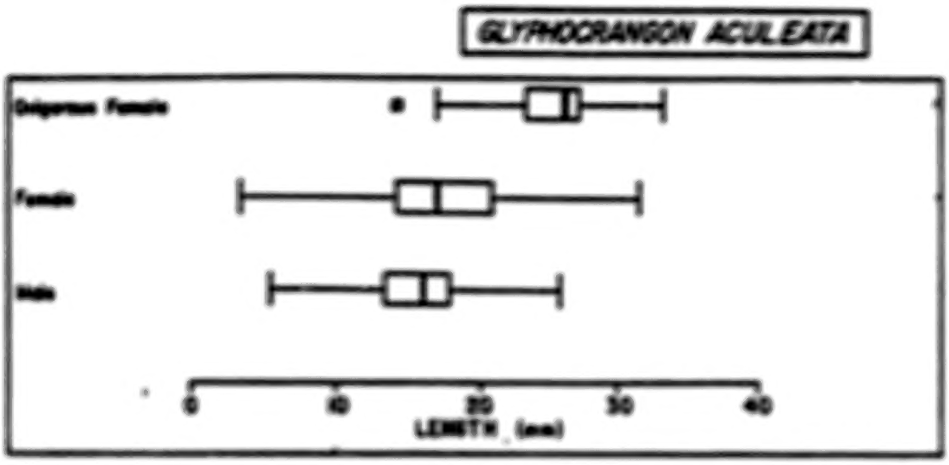


Figure 4-79. Median size (dark vertical bars), 25th and 75th percentiles (boxes), and approximate confidence intervals (whiskers) on carapace lengths of Glyphocrangon aculeata (small squares mark outliers).

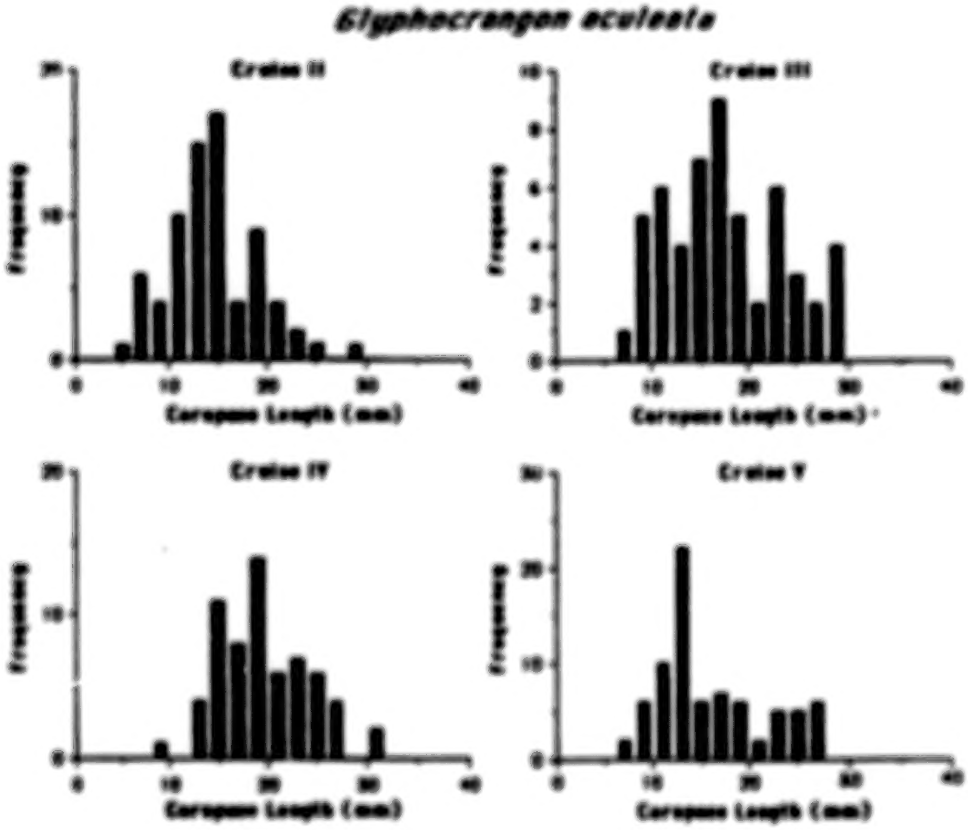


Figure 4-80. Frequency histograms for carapace lengths of Glyphocrangon aculeata from individual cruises.

4.3.4.5 Munida valida (Smith, 1883 Family Galatheidae

Distribution

The long-armed crab, Munida valida, has been collected along the Atlantic coast from New England to Florida, at many locations in the Gulf of Mexico, and in the southern Caribbean and the coast of Colombia (Williams and Wigley 1977). It has been taken swarming near the surface (0-9 m), but has been described more commonly from 90 to 1823 m (Pequegnat and Chace 1970, Williams 1984). There is also a collection record from 2,297 m (Wenner, unpub. ms.). Its maximum population density in the Gulf has been reported at 650 m, in the Archibenthal Zone (Pequegnat 1983).

During this program, Munida valida was collected on all five cruises, at depths ranging from 464 to 1,170 m (Fig. 4-81). Specimens were taken on the Central Transect from 474 to 850 m; on the Eastern Transect from 612 to 1,170 m; on the Western Transect from 654 to 828 m; and on the West Central Transect from 464 to 774 m.

Measurements

Munida valida is the largest species of Munida in the Gulf of Mexico (Pequegnat and Chace 1970). Specimens collected during the Alaminos cruises ranged from 9 to 33 mm in carapace length. The smallest ovigerous female was 21 mm long, taken in November. Other collections have produced ovigerous females almost year-round (Williams 1984; Wenner, unpub. ms.).

In this program, 516 measured specimens ranged from 6 to 37 mm in carapace length, with the largest number of specimens between 10 and 30 mm long (Fig. 4-82A). Females overlapped males in length at both ends of the size range (Fig. 4-83). Only eight of the 307 females measured were ovigerous. Mean length for ovigerous females was 22 mm, within a range of 11 to 33 mm. Non-ovigerous females were between 6 and 37 mm long, with a mean length of 16.6 mm. Males averaged 15.7 mm, and were between 6 and 36 mm long. The overall size frequency distribution formed a bimodal curve as a result of a large number of small specimens (10-15 mm long) having been collected during Cruise V (June 1985) (Fig. 4-84). There was a positive linear correlation (r = 0.99) between the logs of specimen width

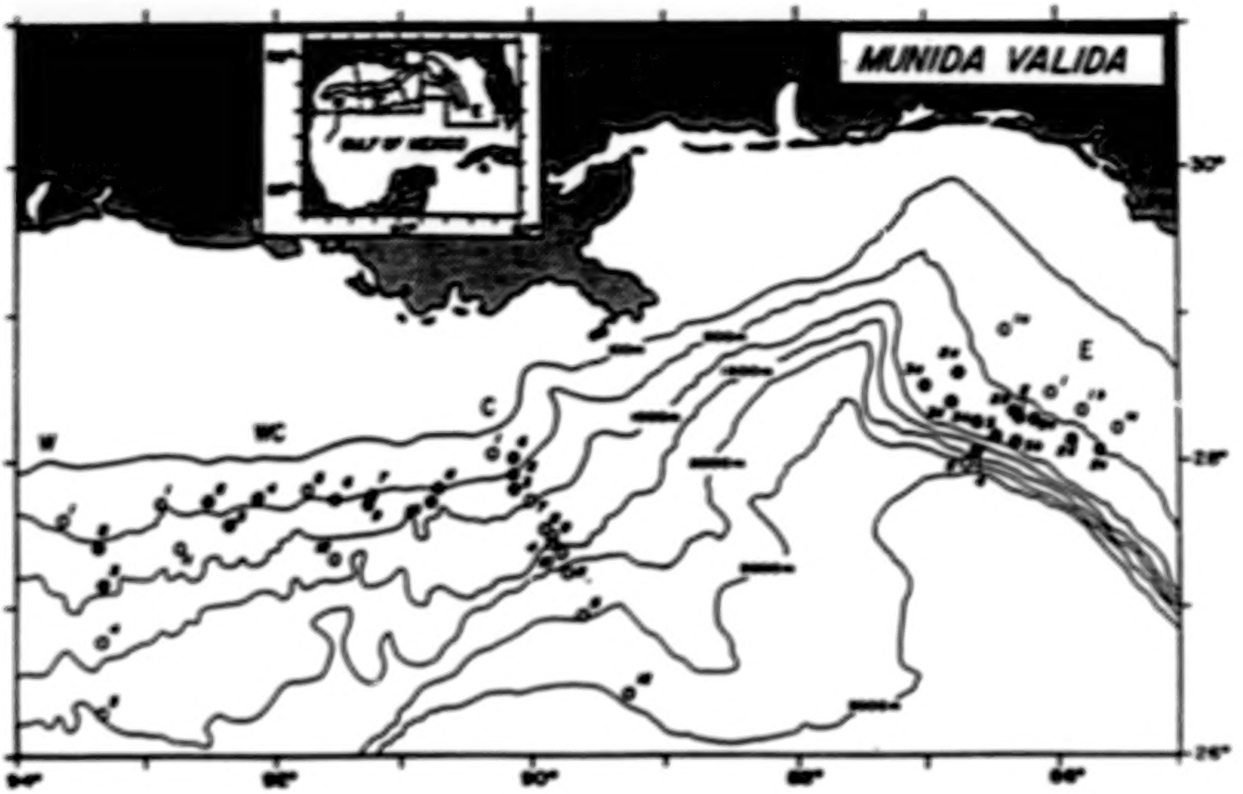


Figure 4-81. Locations where Munida valida were collected (closed circles).

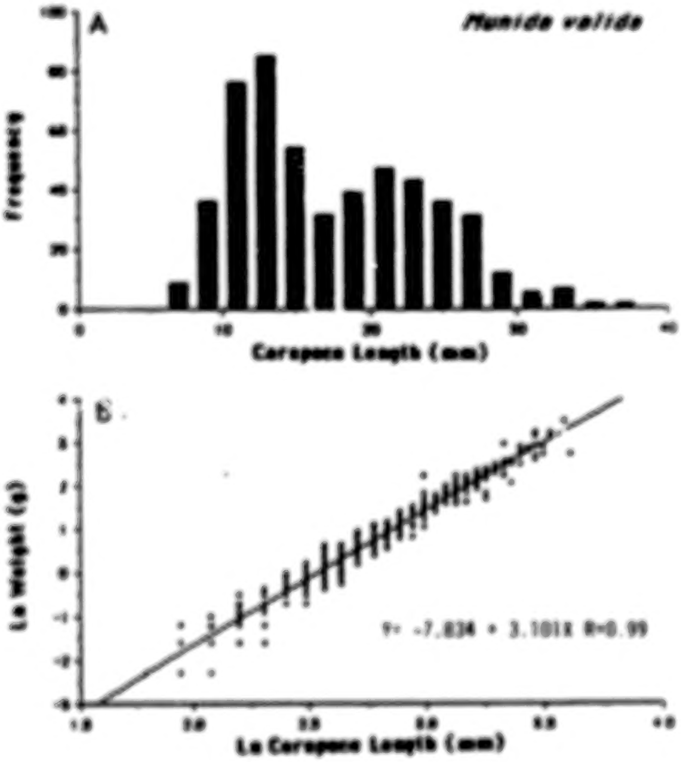


Figure 4-82. Frequency histogram (A) and size-weight relationship (B) for carapace lengths of Munida valida (all stations pooled).

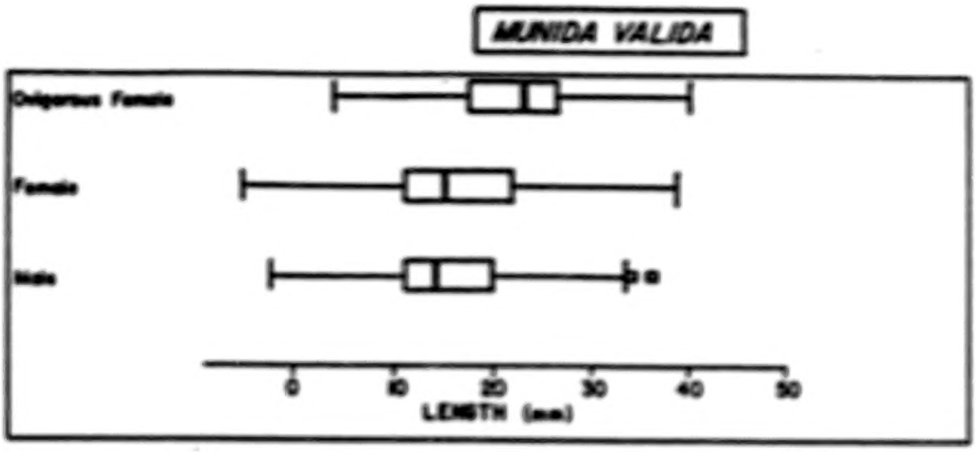


Figure 4-83. Median size (dark vertical bars), 25th and 75th percentiles (boxes), and approximate confidence intervals (whiskers) on carapace lengths of Munida valida (small squares mark outliers).

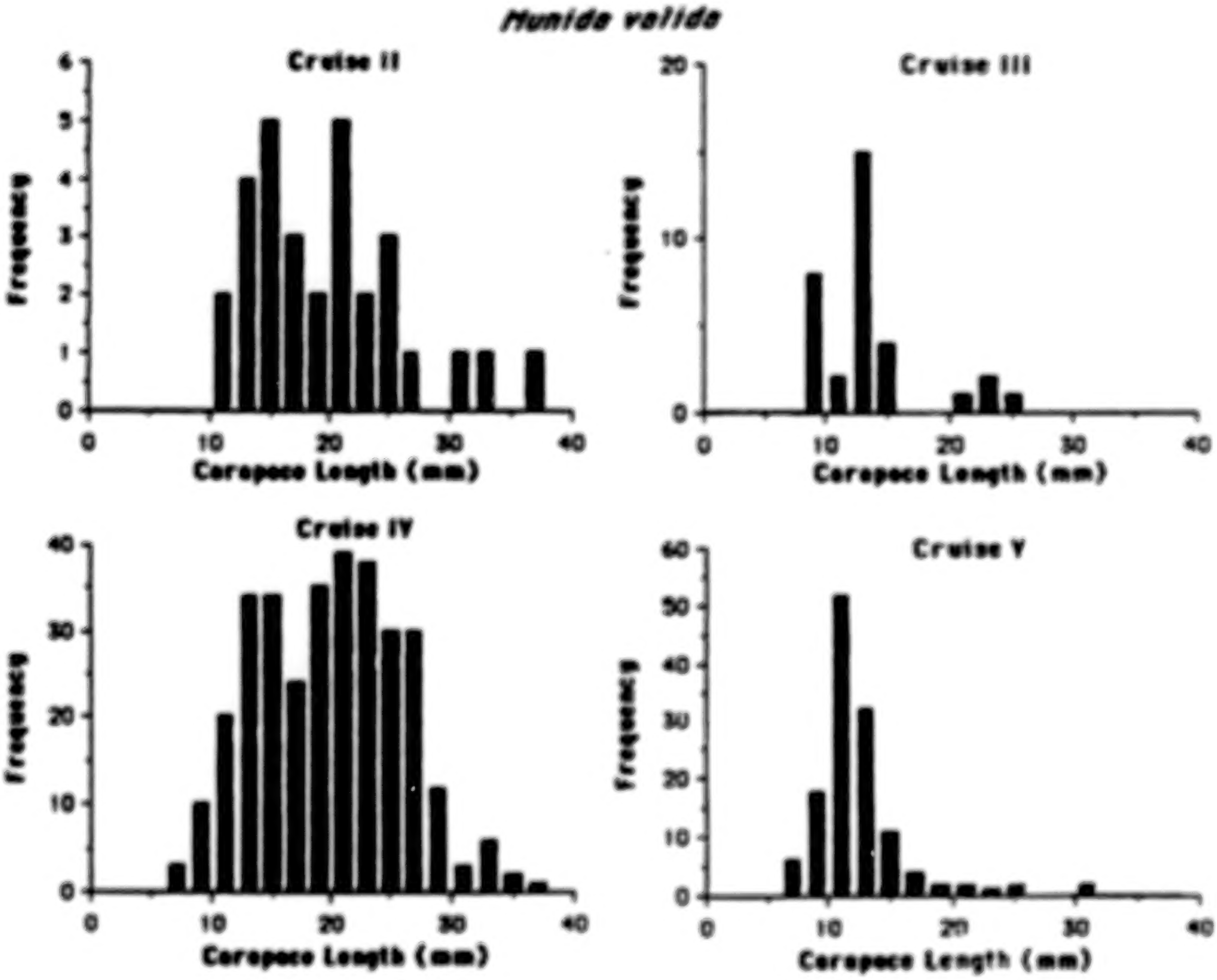


Figure 4-84. Frequency histograms for carapace lengths of Munida valida from individual cruises.

and weight (Fig. 4-82B). Weights ranged between 0.1 and 33.3 g, with a mean of 3.9 g.

4.3.4.6 *Munidopsis robusta* (A. Milne Edwards, 1880 Family Galatheidae)

Distribution

The robust spiny-tailed crab, *Munidopsis robusta*, has been reported throughout the Gulf of Mexico, the western Atlantic, the Straits of Florida, and in the southern Caribbean (Mayo 1974, Pequegnat and Chace 1970). In the Gulf, it has been collected from depths of 110 to 1000 m, inhabiting the Shelf/Slope Transition and Archibenthal Zones, with a population maximum at about 500 m (Pequegnat 1983).

During this program, *Munidopsis robusta* was taken on Cruises 2 through 5, in depths ranging from 342 to 746 m (Fig. 4-85). Specimens were captured on the Central Transect from 346 to 747 m; on the Eastern Transect from 366 to 627 m; on the Western Transect at 342 m; and on the West Central Transect from 423 to 746 m.

Measurements

Munidopsis robusta specimens collected during the *Alaminos* cruises were between 7 and 20 mm in carapace length. Ovigerous females between 13 and 20 mm long were present in August and November.

Specimens measured during this program were similar in size to those collected during the *Alaminos* cruises. The 81 individuals measured were between 10 and 20 mm in length, and averaged 15.6 mm long. Their frequency distribution was unimodal, with the greatest number of individuals between 14 and 18 mm long (Fig. 4-86A). Females tended to be slightly larger than did males (Fig. 4-87). Mean carapace length for ovigerous females was 16.6 mm, within a range of 14 to 19 mm. Non-ovigerous females averaged 15.3 mm in length, and were betweeen 8 and 20 mm long. Males ranged from 7 to 19 mm long, with a mean of 14.7 mm. There were no obvious seasonal differences in length frequency distributions (Fig. 4-88). There was a positive linear correlation (r = 0.93) between the logs of specimen width and weight (Fig. 4-86B), although smaller specimens were proportionately heavier per unit length. Mean weight was 3.0 g, within a range of 0.4 to 5.8 g.

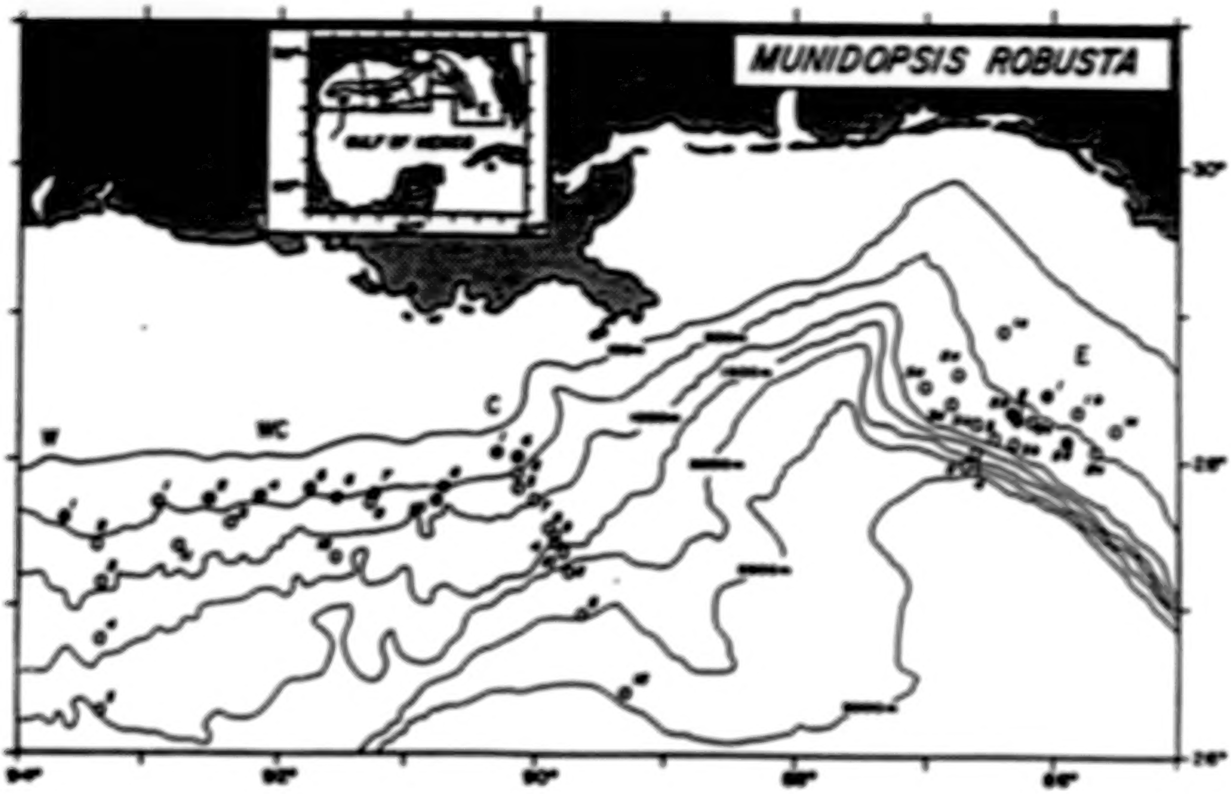


Figure 4-85. Locations where *Munidopsis robusta* were collected (closed circles).

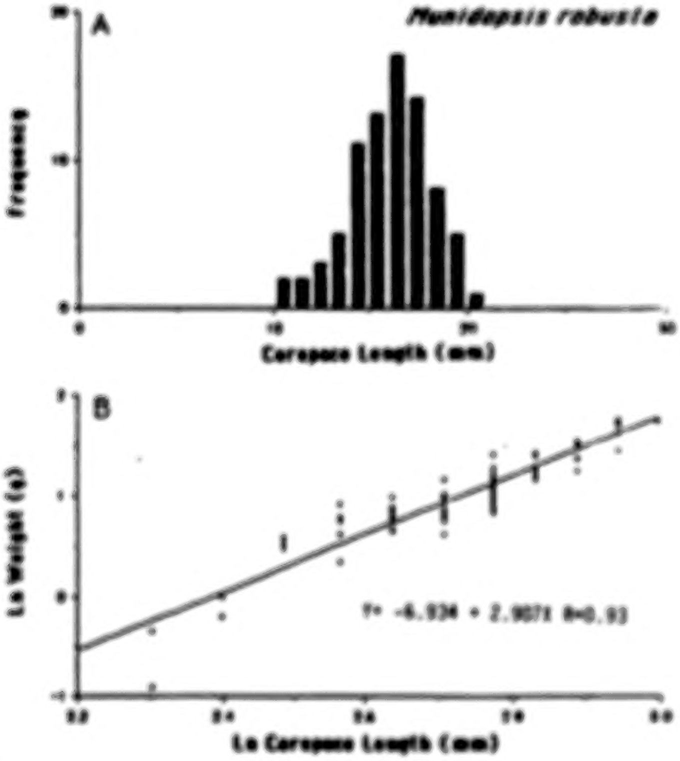


Figure 4-86. Frequency histogram (A) and size-weight relationship (B) for carapace lengths of *Munidopsis robusta* (all stations pooled).

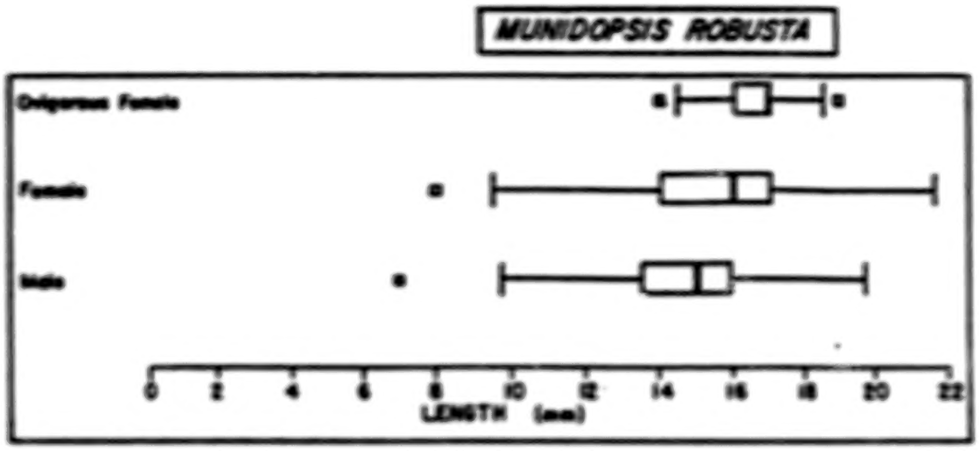


Figure 4-87. Median size (dark vertical bars), 25th and 75th percentiles (boxes), and approximate confidence intervals (whiskers) on carapace lengths of Munidopsis robusta (small squares mark outliers).

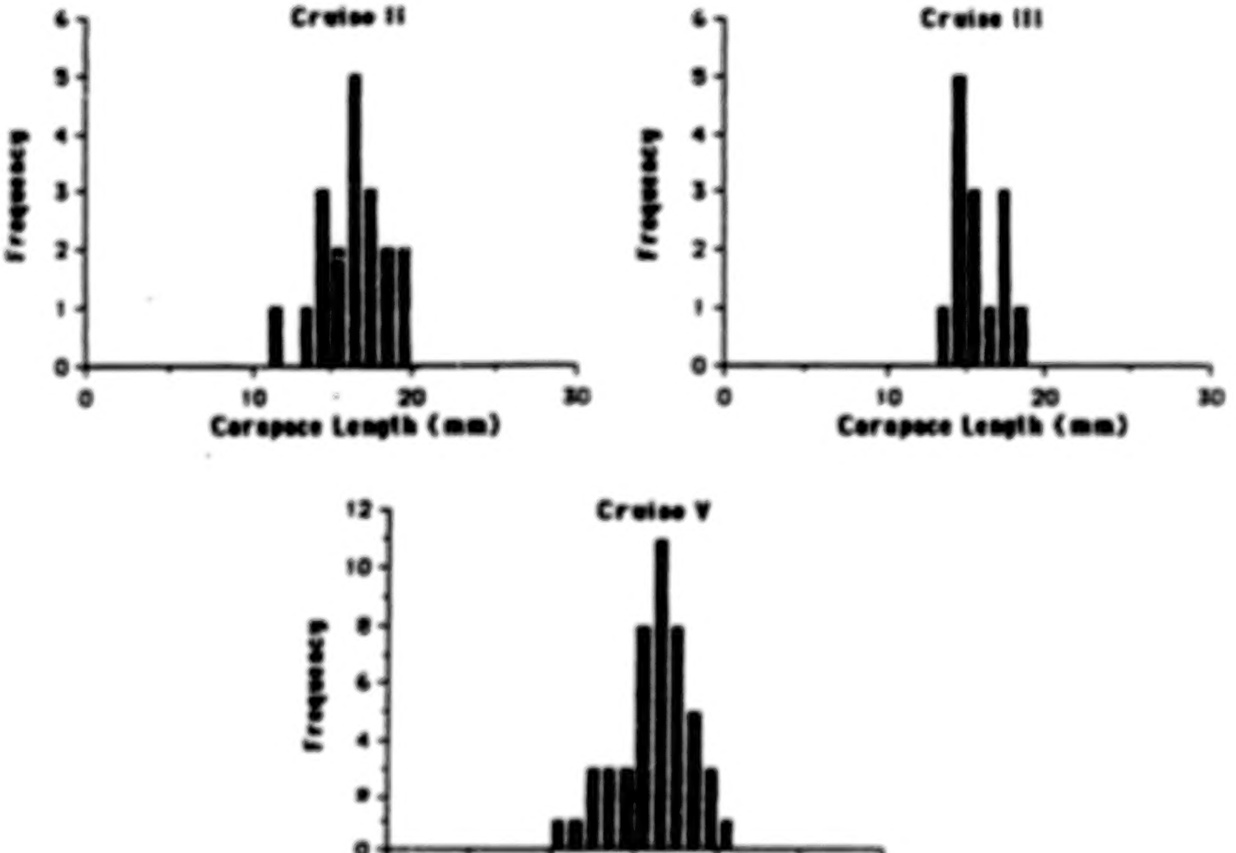


Figure 4-88. Frequency histograms for carapace lengths of Munidopsis robusta from individual cruises.

4.3.4.7 Nematocarcinus rotundus (Crosnier & Forest, 1973 Family Nematocarcinidae)

Distribution

Nematocarcinus rotundus, the thread-footed shrimp, was not separated taxonomically from *N. cursor*, a closely related species, until 1973 (Crosnier and Forest 1973). Therefore, descriptions of *N. cursor* prior to that date may refer to either (or both) species, as well as a third (*N. africanus*) not discussed here.

Nematocarcinus rotundus is a very widely distributed caridean in the Caribbean and Atlantic. It is known from depths of 330-380 m to 1,240 m (Crosnier and Forest 1973), having been collected in the southern Caribbean, the Gulf of Mexico, along the coast of South America, and the southwestern Atlantic coast of the United States (Williams and Wigley 1977).

Specimens collected in the Gulf of Mexico during the *Alaminos* cruises were taken across the upper continental slope from 512 to 1,829 m, with a population density peak in the upper portion of the Upper Abyssal Zone, near 1,050 m (Pequegnat et al. 1971, Pequegnat 1983). *Nematocarcinus rotundus* was the most abundant and widespread caridean collected.

During this program, *Nematocarcinus rotundus* was collected on all five cruises, at nearly every station between 500 m and 1,000 m, and spanning a depth range of 521 to 1,510 m (Fig. 4-89). Specimens were taken on the Central Transect from 603 to 1,510 m; on the Eastern Transect from 612 to 1,170 m; on the Western Transect from 654 to 1,413 m; and on the West Central Transect from 521 to 1,206 m.

Measurements

Specimens of *Nematocarcinus rotundus* taken during the *Alaminos* cruises were between 9 and 27 mm carapace length, with the smallest ovigerous female 20 mm long. Ovigerous females were collected during July, August, and November.

During this program, 1,060 measured *Nematocarcinus rotundus* were between 9 and 30 mm in carapace length, and averaged 19.1 mm (Fig. 4-90A).

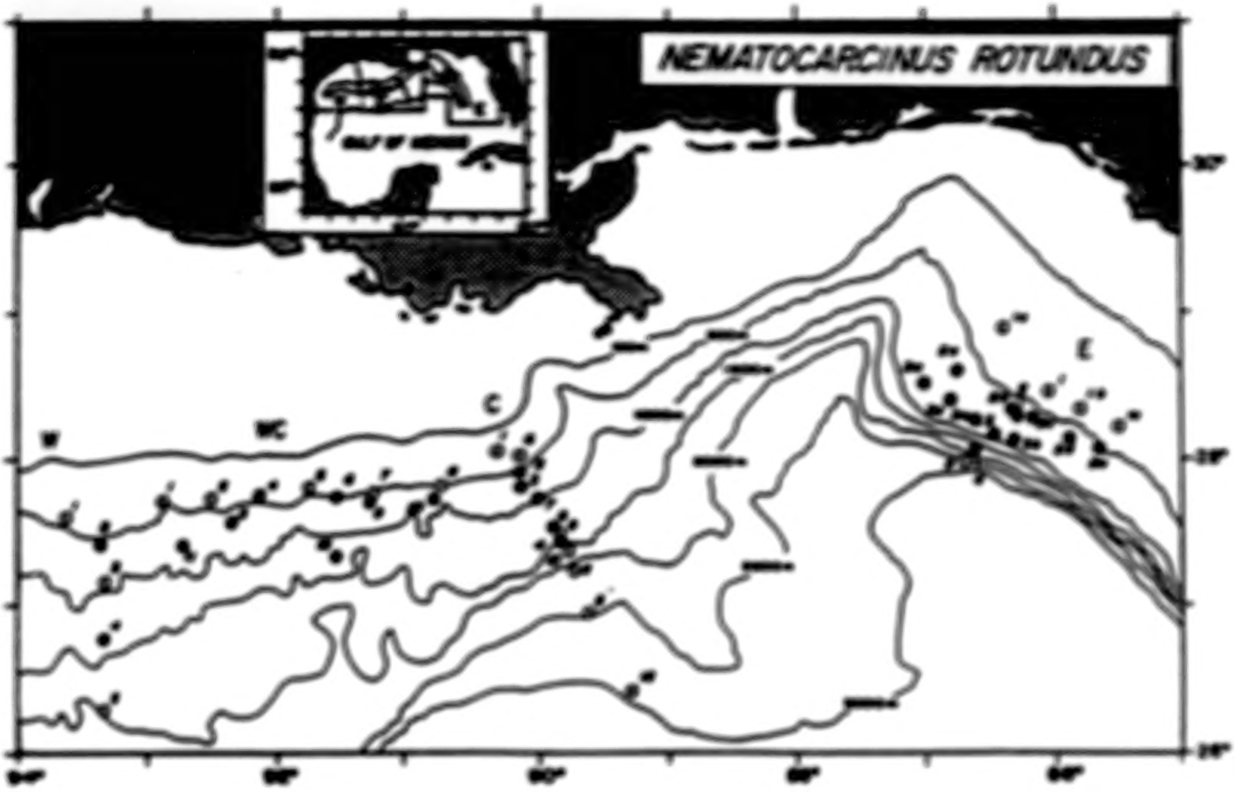


Figure 4-89. Locations where Nematocarcinus rotundus were collected (closed circles).

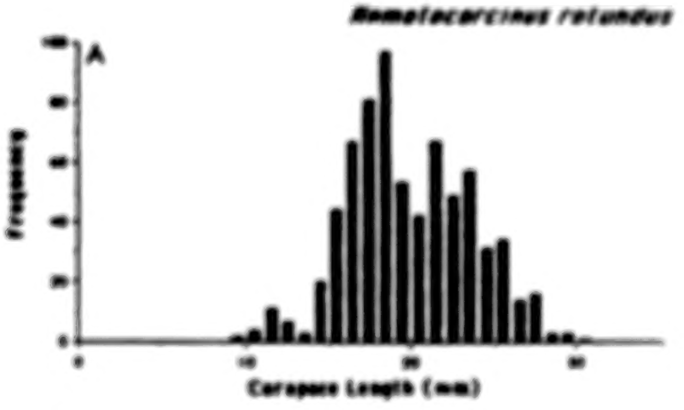


Figure 4-90. Frequency histogram (A) and size-weight relationship (B) for carapace lengths of Nematocarcinus rotundus (all stations pooled).

There was little difference in the size ranges of males and females, although males did tend to be slightly smaller than females (Fig. 4-91). Ovigerous females averaged 21.7 mm long, and ranged between 10 and 29 mm. More than half of the females measured (284 out of 543) were ovigerous. Non-ovigerous females had a mean carapace length of 18.7 mm, within a range of 9 to 30 mm. Males were between 9 and 28 mm long, with a mean length of 17.1 mm. There appeared to be a break in the frequency distribution near 20 mm, which could also be seen in the cruise-by-cruise size frequency distribution graphs (Fig. 4-92). The break was probably due to size differences between ovigerous and non-ovigerous females. There was a positive linear relationship (r = 0.95) between the logs of weight and carapace length (Fig. 4-90B). Mean weight was 3.0 g, within a range of 0.1 to 11.5 g.

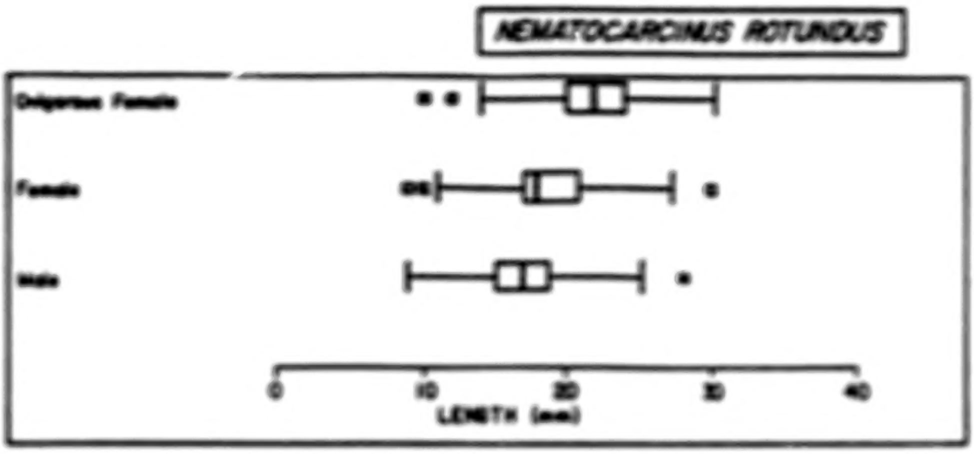


Figure 4-91. Median size (dark vertical bars), 25th and 75th percentiles (boxes), and approximate confidence intervals (whiskers) on carapace lengths of _Nematocarcinus_ _rotundus_ (small squares mark outliers).

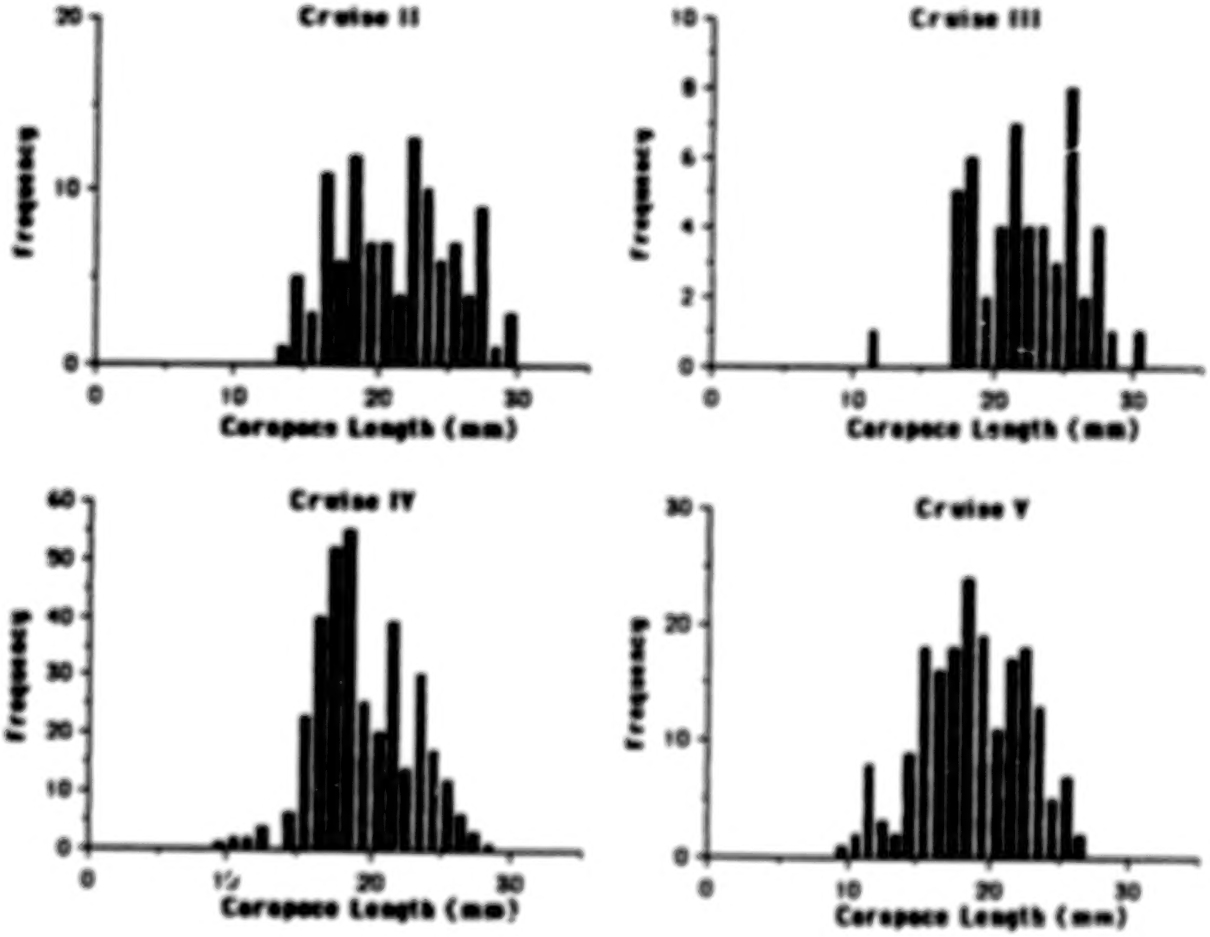


Figure 4-92. Frequency histograms for carapace lengths of _Nematocarcinus_ _rotundus_ from individual cruises.

4.3.4.8 Penaeopsis serrata (Bate, 1881 Family Penaeidae)

Distribution

The big-eyed shrimp, *Penaeopsis serrata*, is the most abundant deep-water penaeid in the Gulf of Mexico, being especially common near the upper edge of the continental slope (Pequegnat and Chace 1970, Pequegnat et al. 1971). Large numbers have been taken in the De Soto Canyon in water about 370 m deep, and off the Rio Grande (about 275 m deep). It is found in the subtropical Atlantic north of the equator, from the Caribbean to South Carolina, and along the west coast of Africa. Pequegnat (1983) described it as present in the *Alaminos* samples from 200 to 550 m depths, with a population peak in the Shelf/Slope Transition Zone at 300 m.

During this program, *Penaeopsis serrata* was collected on all five cruises, within a fairly narrow depth range: from 329 to 464 m (Fig. 4-93). Specimens were taken on the Central Transect from 329 to 346 m; on the Eastern Transect from 345 to 366 m; on the Western Transect at 342 m; and on the West Central Transect from 368 to 464 m.

Measurements

Specimens of 520 *Penaeopsis serrata* measured in this program ranged from 8 to 32 mm in carapace length (Fig. 4-94A). The overall size frequency distribution formed a bell-shaped, unimodal curve. Mean length was 19.3 mm. Males tended to be somewhat smaller than did females (Fig. 4-95), and females achieved greater maximum sizes. Mean length for females was 23.1 mm, within a range of 12 to 32 mm. Males were between 12 and 26 mm, with a mean length of 19.3 mm. No obvious seasonal trends in size frequencies were evident (Fig. 4-96). There was a positive linear correlation (r = 0.89) between the logs of specimen length and weight (Fig. 4-94B). Mean weight was 6.0 g, within a range of 0.2 and 13.2 g.

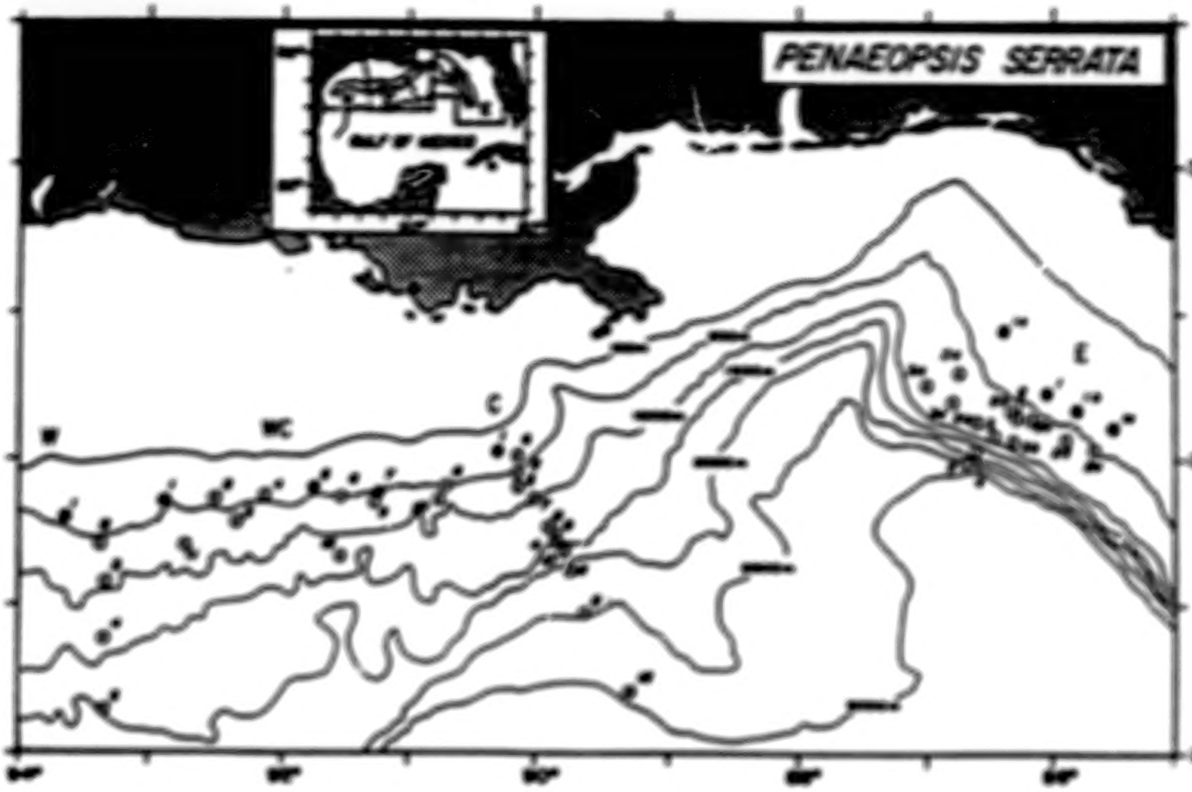


Figure 4-93. Locations where Penaeopsis serrata were collected (closed circles).

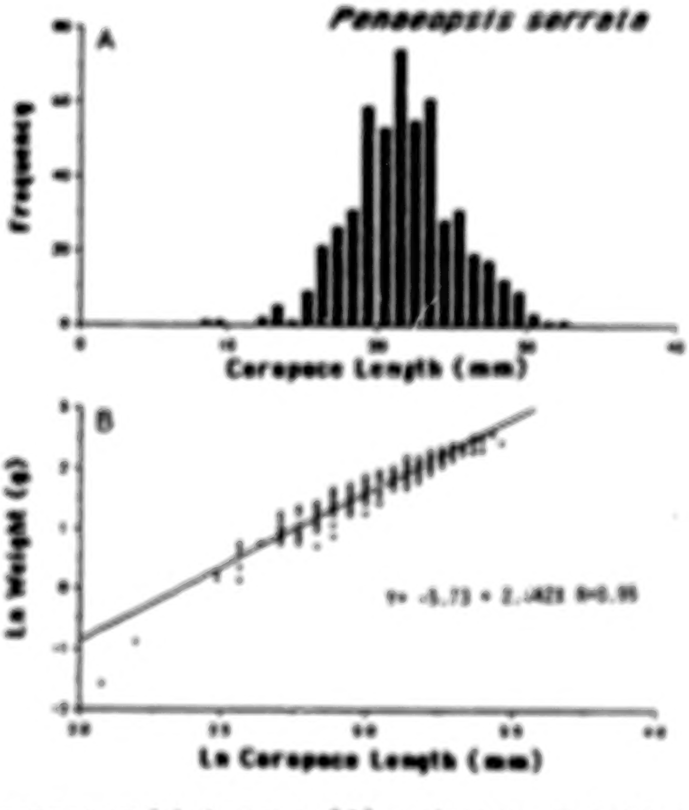


Figure 4-94. Frequency histogram (A) and size-weight relationship (B) for carapace lengths of Penaeopsis serrata (all stations pooled).

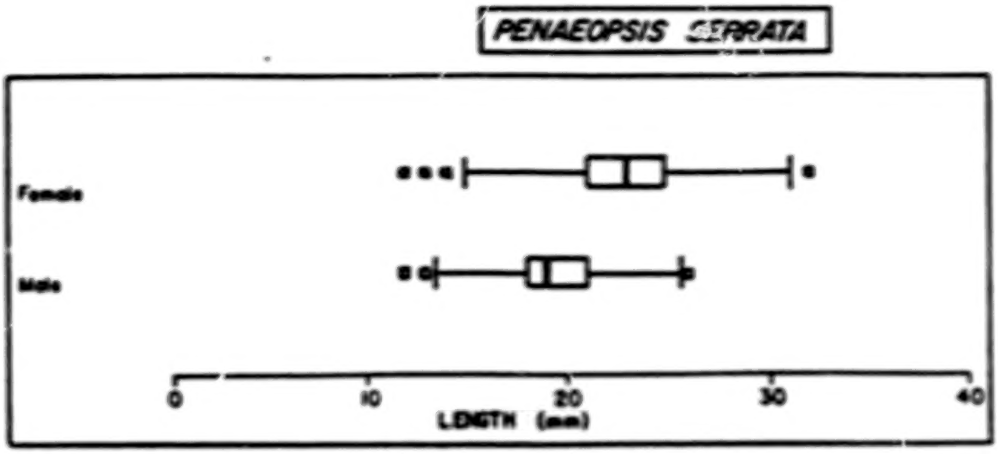


Figure 4-95. Median size (dark vertical bars), 25th and 75th percentiles (boxes), and approximate confidence intervals (whiskers) on carapace lengths of Penaeopsis serrata (small squares mark outliers).

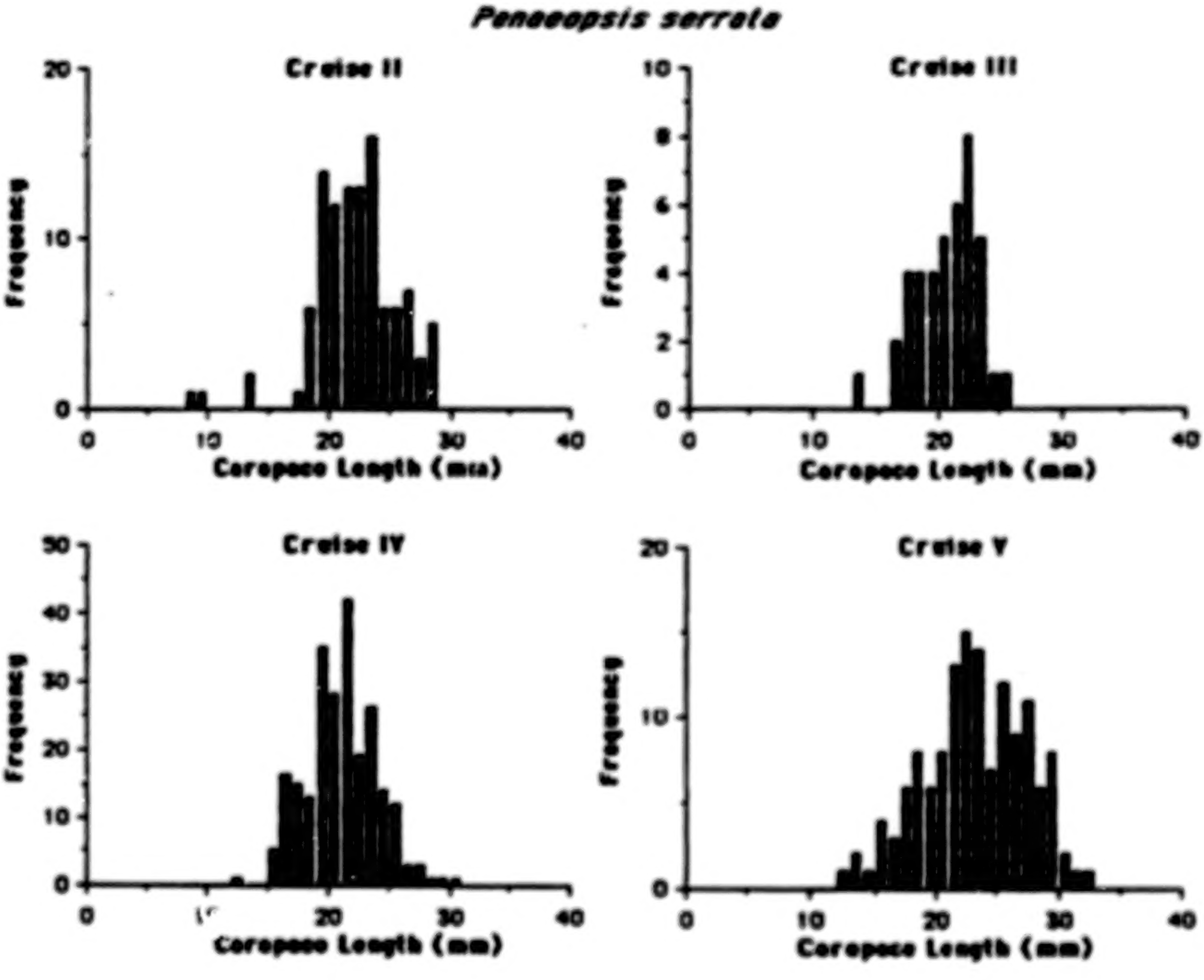


Figure 4-96. Frequency histograms for carapace lengths of Penaeopsis serrata from individual cruises.

4.3.4.9 Plesionika holthuisi (Crosnier & Forest, 1967 Family Pandalidae)

Distribution

Holthuis's pandalid shrimp, Plesionika holthuisi is a widely distributed caridean that has been collected on the west coast of Africa in water 500 m deep, and in the northern Gulf of Mexico between 479 and 864 m (Pequegnat and Chace 1970). It has been described as the most abundant deep-water pandalid in the Gulf above 800 m (Pequegnat et al. 1971). Pequegnat (1983) ascribed a depth range of 500 to 900 m to Plesionika holthuisi, with a population maximum in the Archibenthal Zone at 650 m.

During this program, Plesionika holthuisi was collected on all five cruises, within a depth range of 366 to 871 m (Fig. 4-97). Specimens were taken on the Central Transect from 474 to 850 m; on the Eastern Transect from 366 to 871 m; on the Western Transect at 654 m; and on the West Central Transect from 464 to 774 m.

Measurements

Specimens of Plesionika holthuisi collected during the Alaminos cruises were between 6 and 18 mm in carapace length. Ovigerous females were 9 to 14 mm long, and were collected in July, October, and November (Pequegnat and Chace 1970).

The 459 individuals of Plesionika holthuisi measured in this program averaged 11.2 mm in carapace length, and ranged from 5 to 17 mm (Fig. 4-98A). Males and females were quite similar in size (Fig. 4-99). Mean length for ovigerous females was 11.8 mm, within a range of 8 to 17 mm. About two thirds (216 out of 333) of the females that were measured were ovigerous. Non-ovigerous females averaged 11 mm in length, and were between 6 and 16 mm long. Males averaged 10.7 mm in length, and were between 6 and 16 mm long. The overall frequency distribution for P. holthuisi formed a bell-shaped, unimodal curve, without obvious seasonal trends (Fig. 4-100). There was a positive linear correlation (r = 0.89) between the logs of specimen width and weight (Fig. 4-98B). Mean weight was 1.1 g, within a range of 0.2 to 3.9 g.

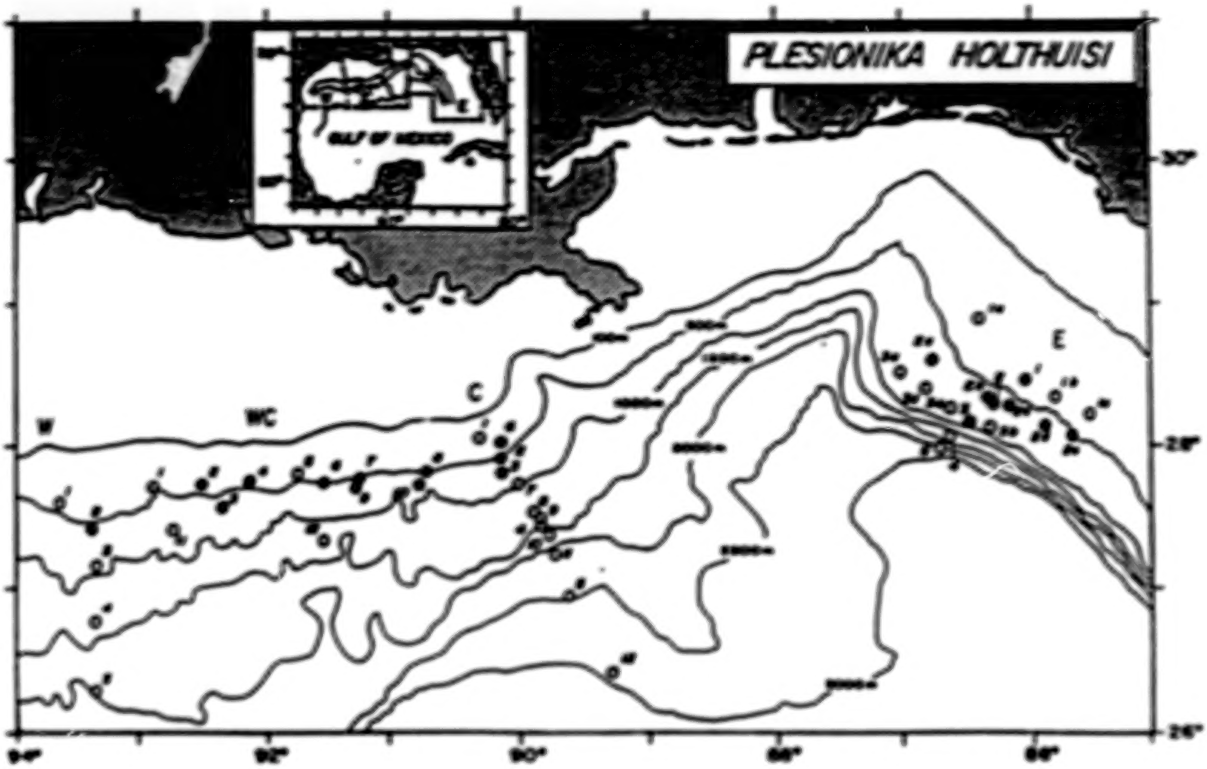


Figure 4-97. Locations where Plesionika holthuisi were collected (closed circles).

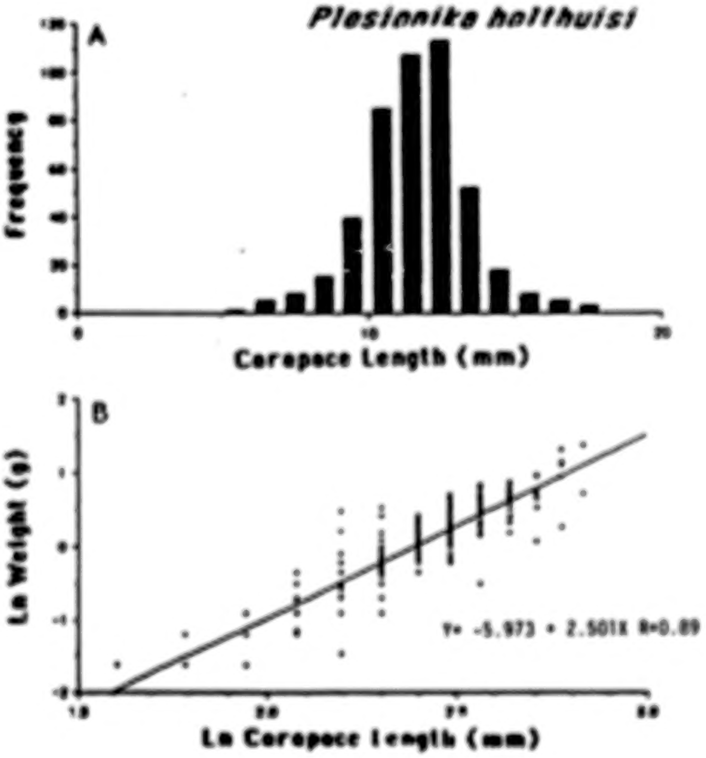


Figure 4-98. Frequency histogram (A) and size-weight relationship (B) for carapace lengths of Plesionika holthuisi (all stations pooled).

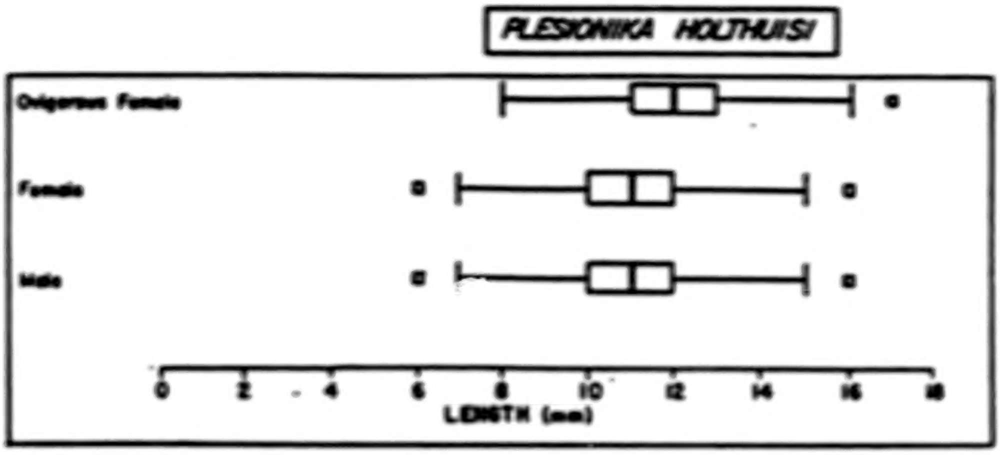


Figure 4-99. Median size (dark vertical bars), 25th and 75th percentiles (boxes), and approximate confidence intervals (whiskers) on carapace lengths of Plesionika holthuisi (small squares mark outliers).

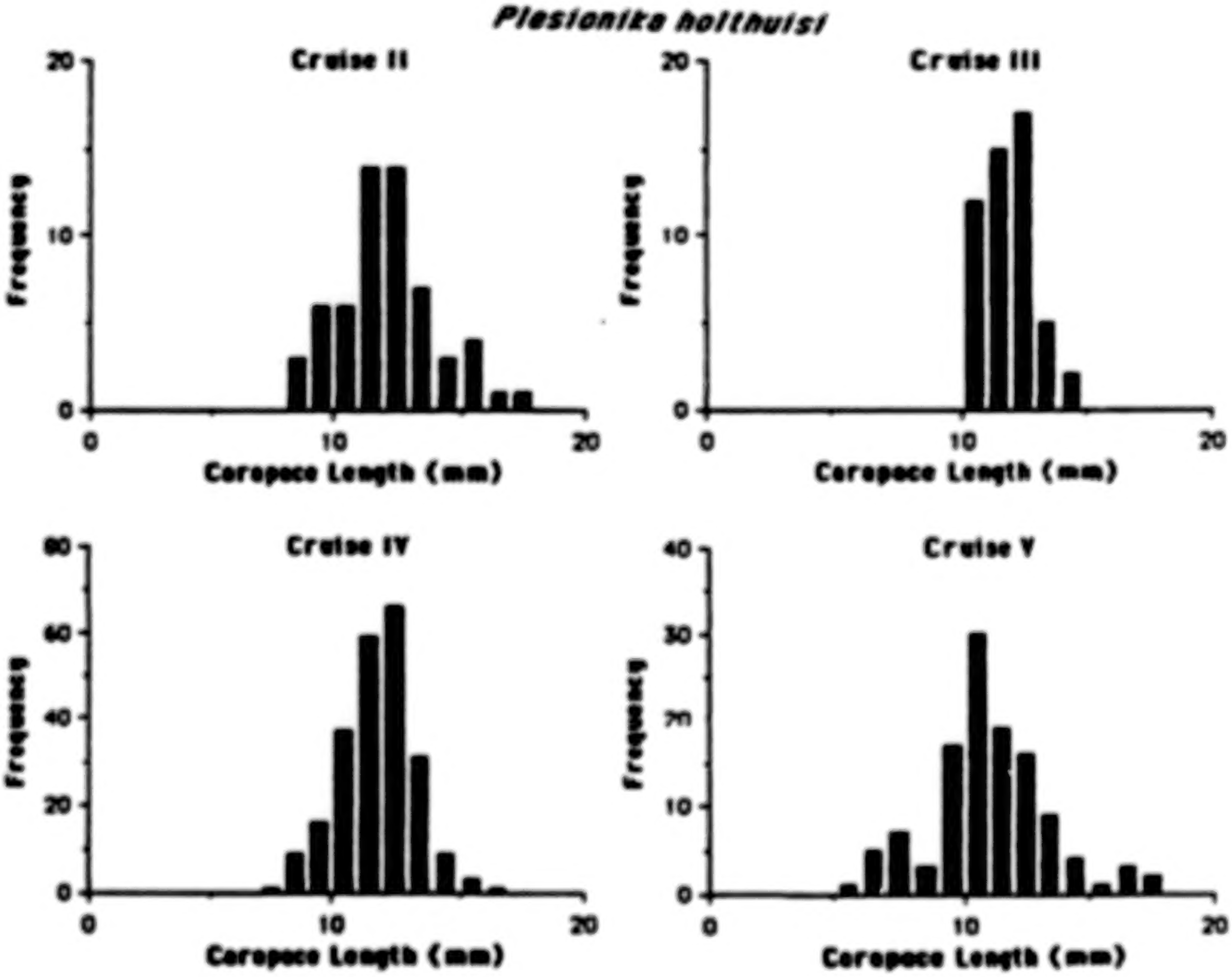


Figure 4-100. Frequency histograms for carapace lengths of Plesionika holthuisi from individual cruises.

4.3.4.10 Rochinia crassa (A. Milne Edwards, 1879 Family Majidae)

Distribution

Rochinia crassa, the short-clawed spider crab, is found in water along the Atlantic coast of the US from New England to the Straits of Florida, and throughout the Gulf of Mexico except the southwest portion (Pequegnat and Chace 1970). The Alaminos collection includes six specimens from between 382 and 728 m; deeper records exist off Cuba (Chace 1940). In the Straits of Florida, it has a somewhat shallower distribution, from 180 to 642 m, and is apparently confined to water colder than 10°C (Soto 1982). Soto states that it is "exclusively (a) mud dweller."

During this program, Rochinia crassa was collected on Cruises II through V, over a depth range of 338 to 1,170 m (Fig. 4-101). Specimens were taken on the Central Transect from 338 to 632 m; on the Eastern Transect from 351 to 1,170 m; on the Western Transect at 342 m; and on the West Central Transect from 368 to 751 m.

Measurements

Those few specimens of Rochinia crassa collected by the Alaminos were between 11 and 72 mm in carapace width (Pequegnat and Chace 1970).

In this study, 51 measured specimens of Rochinia crassa were between 9 and 126 mm in carapace width. Males had a mean width of 37.6 mm, within a range of 14 to 126 mm. Non-ovigerous females were from 10 to 56 mm wide, with a mean of 30.6 mm. Ovigerous females had a mean width of 63.1 mm, and were between 57 and 70 mm wide.

The size frequency distribution showed some evidence of bimodality (Fig. 4-102A), but sample size was too small to permit the differentiation of seasonal trends (Fig. 4-103). Most specimens were less than 50 mm wide, but there was a second apparent peak in size, with very large males making up the second peak (Fig. 4-104). This may have been due to sexual dimorphism, although biased handling of specimens on deck (catch selection) was known to have taken place for this species. There was a positive linear relationship (r = 0.97) between the logs of weight and

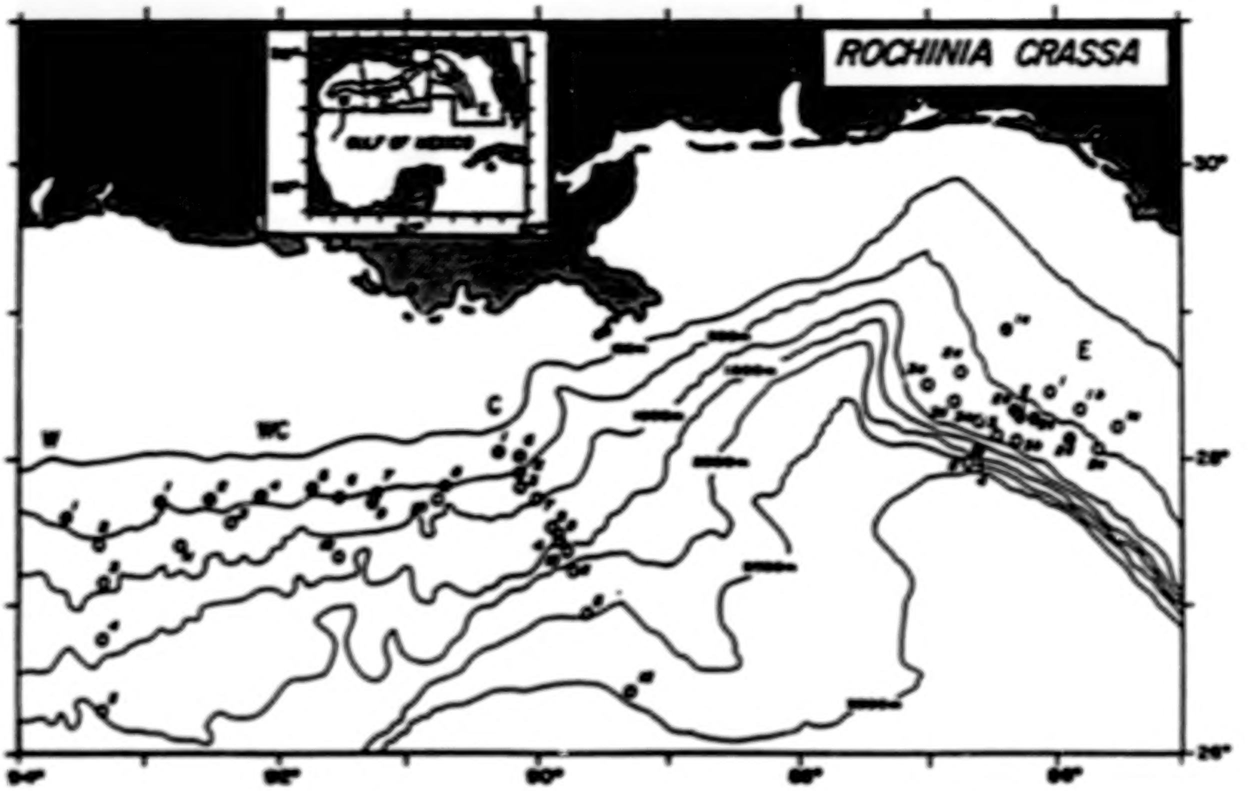


Figure 4-101. Locations where Rochinia crassa were collected (closed circles).

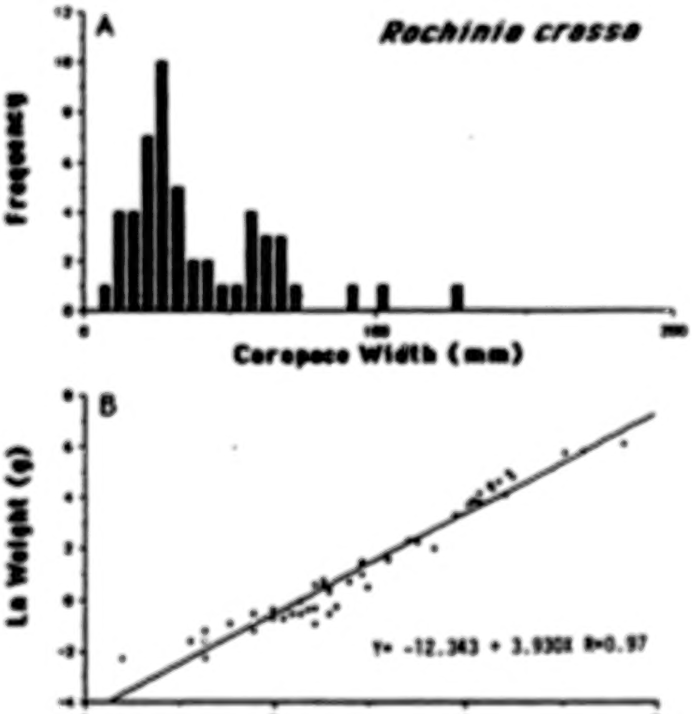


Figure 4-102. Frequency histogram (A) and size-weight relationship (B) for carapace widths of Rochinia crassa (all stations pooled).

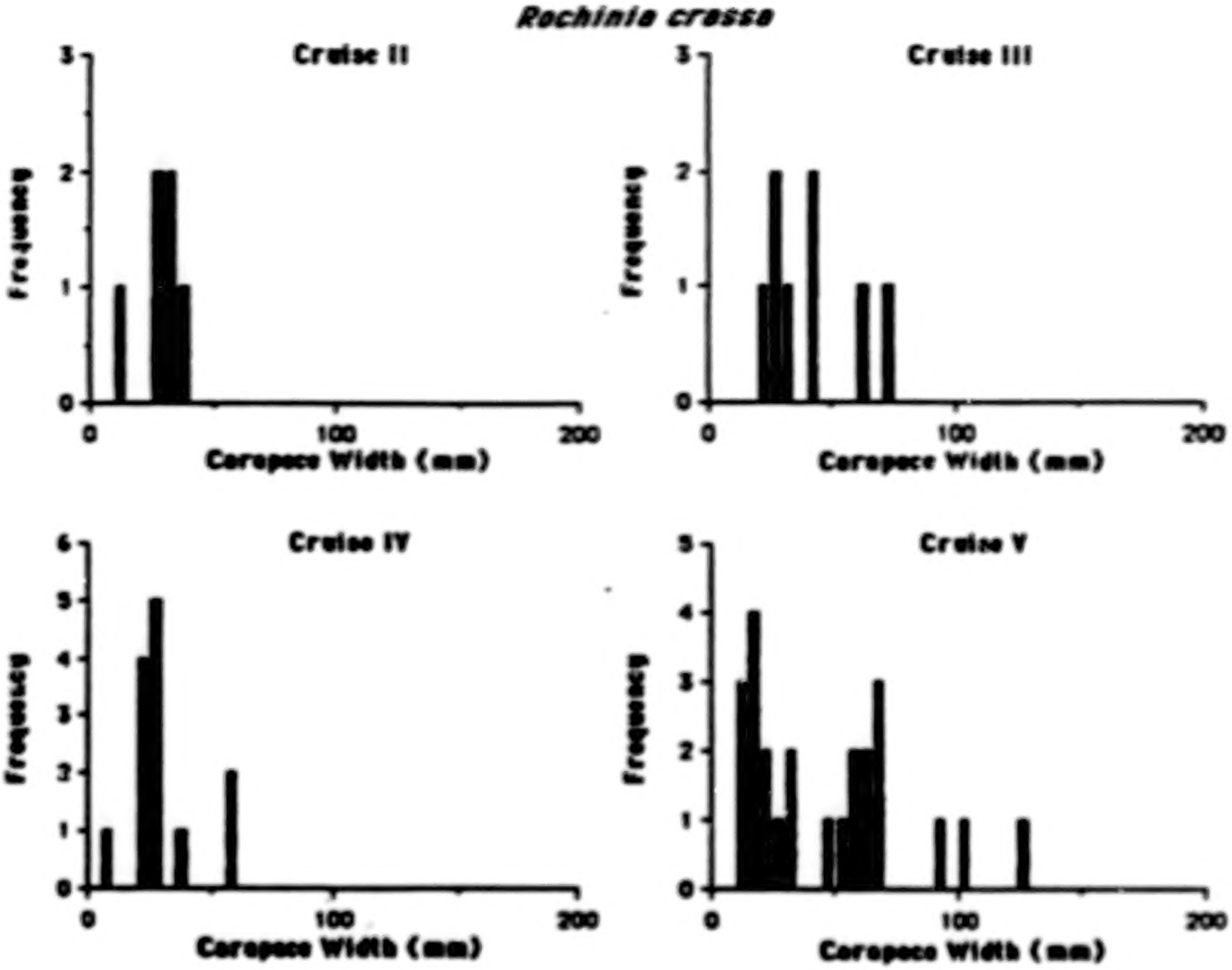


Figure 4-103. Frequency histograms for carapace widths of Rochinia crassa from individual cruises.

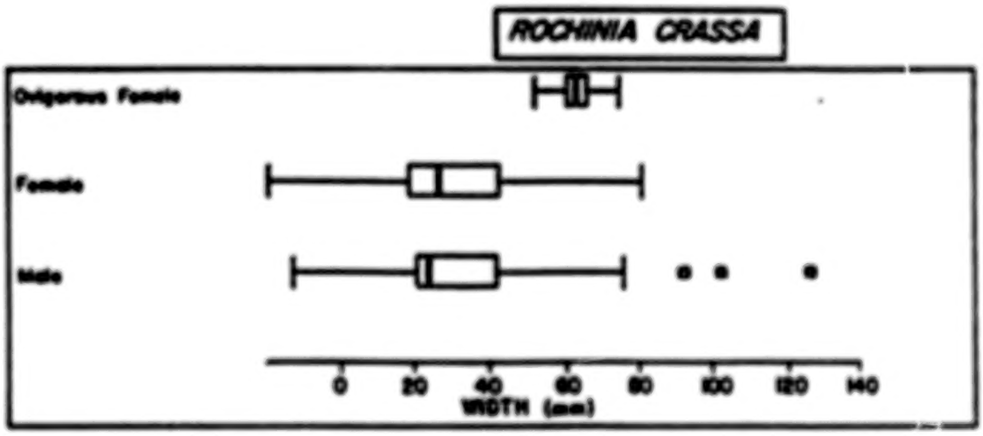


Figure 4-104. Median size (dark vertical bars), 25th and 75th percentiles (boxes), and approximate confidence intervals (whiskers) on carapace widths of Rochinia crassa (small squares mark outliers).

carapace length (Fig. 4-102B) Mean weight was 41.6 g, within a range of 0.1 to 454.9 g.

4.3.4.11 Stereomastis sculpta (S. Smith, 1882 Family Polychelidae)

Distribution

The flat-backed lobsterette, *Stereomastis sculpta*, is one of the most widely distributed polychelids. The subspecies *Stereomastis sculpta sculpta* has been reported from the eastern Atlantic, Mediterranean, and the Indo-Pacific near Indonesia, the Arabian Sea, as well as the Gulf of Mexico and the Caribbean (Firth and Pequegnat 1971, Kensley 1981, Williams and Wigley 1977). Another subspecies, *S. sculpta pacifica*, replaces it in the eastern Pacific. The depth range of *S. sculpta sculpta* is from 230 to 4,000 m. It is the most frequently captured polychelid in the Gulf and the Caribbean, having been taken by the *Alaminos* in depths of 476 to 1875 m. It is abundant enough to have been considered for commercial fisheries (BCF 1969). Its depth range in the Gulf has been given by Pequegnat (1983) as from 500 to 2,750 m, with maximum population density in the Upper Abyssal Zone at 1,050 m.

Stereomastis sculpta was collected during this program on all five cruises, at depths from 603 to 2,357 m (Fig. 4-105). Specimens were taken on the Central Transect from 603 to 1,510 m; on the Eastern Transect from 612 to 2,857 m; on the Western Transect from 828 m to 1,413 m; and on the West Central Transect from 663 to 1,206 m.

Measurements

Specimens of *Stereomastis sculpta* collected during the *Alaminos* cruises were from 17 to 70 mm in carapace length, with ovigerous females 43 to 58 mm long, and ovigerous females with spermatophores attached between 41 and 70 mm long.

During this program, 430 measured individuals of *Stereomastis sculpta* ranged from 15 to 61 mm in carapace length, averaging 33.4 mm (Fig. 4-106A). Mean length for males was 34.1 mm, within a range of 17 to 42 mm. Non-ovigerous females were between 16 and 58 mm long, with a mean of 32.5 mm. Ovigerous females had a mean length of 51.8 mm, and were between 44 and 61 mm long. Females overlapped males at both ends of their size range (Fig. 4-107). Their overall frequency distribution formed a bell-shaped,

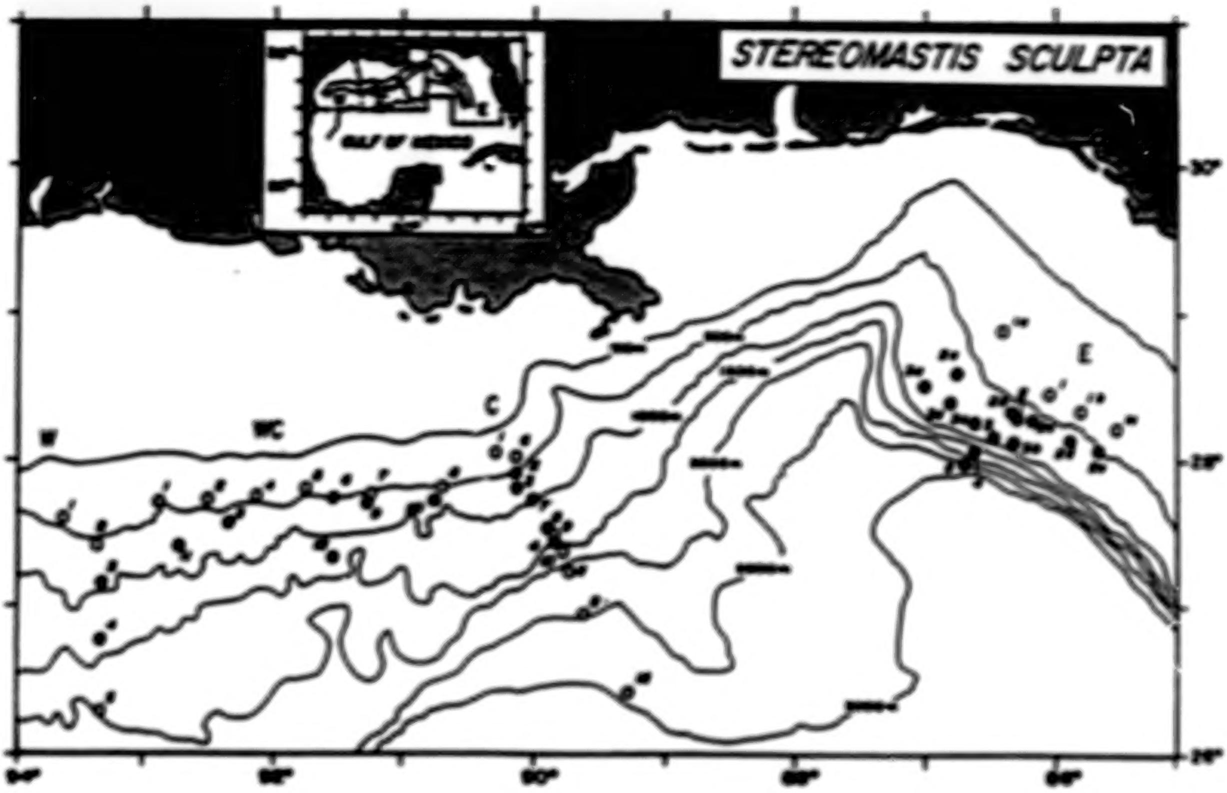


Figure 4-105. Locations where Stereomastis sculpta were collected (closed circles).

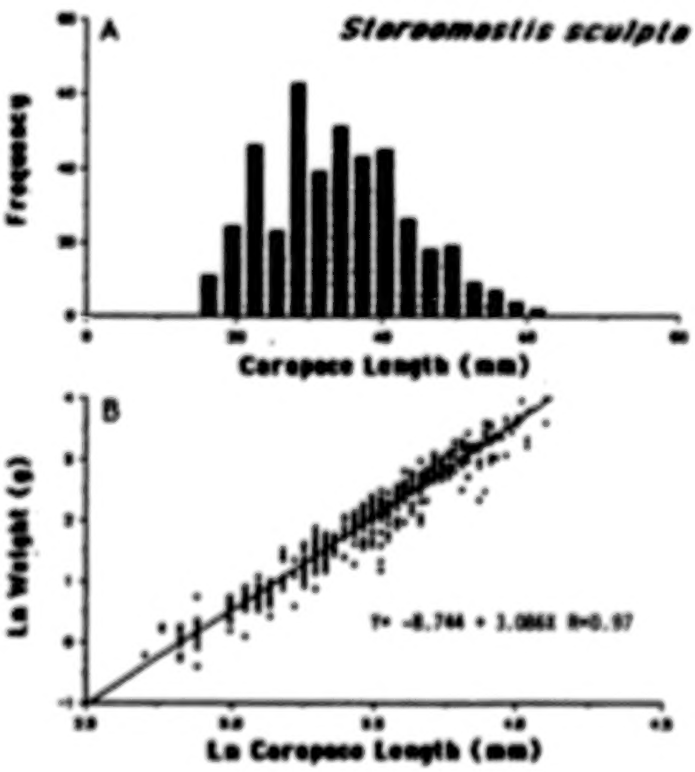


Figure 4-106. Frequency histogram (A) and size-weight relationship (B) for carapace lengths of Stereomastis sculpta (all stations pooled).

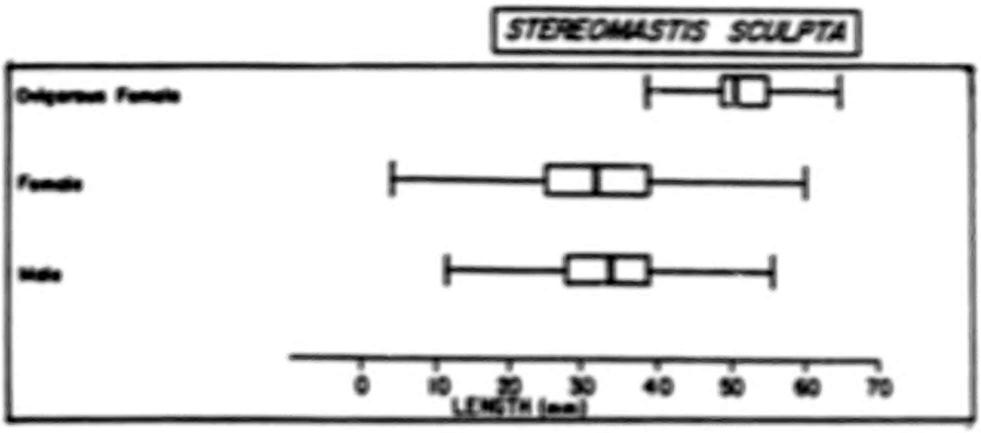


Figure 4-107. Median size (dark vertical bars), 25th and 75th percentiles (boxes), and approximate confidence intervals (whiskers) on carapace lengths of Stereomastis sculpta (small squares mark outliers).

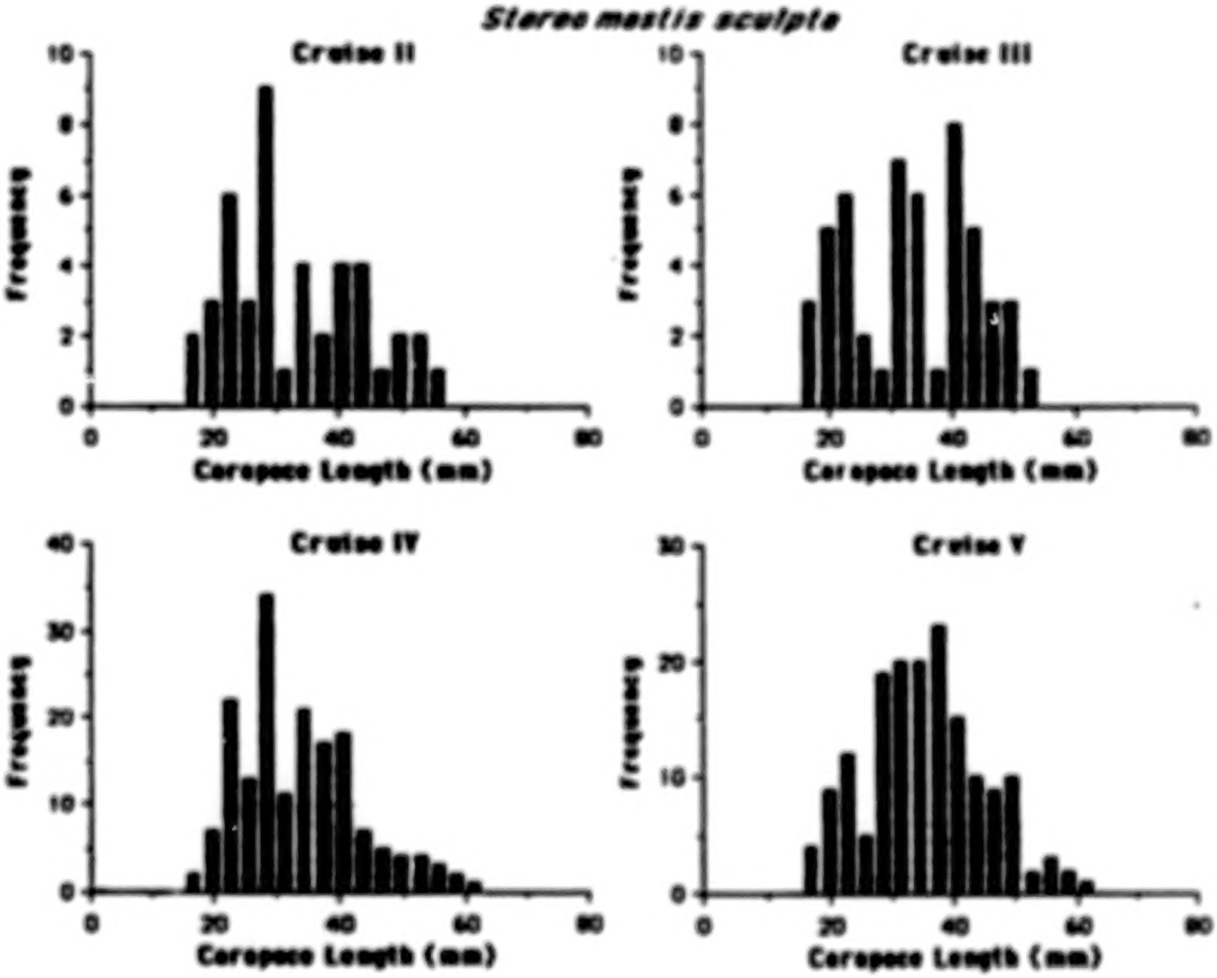
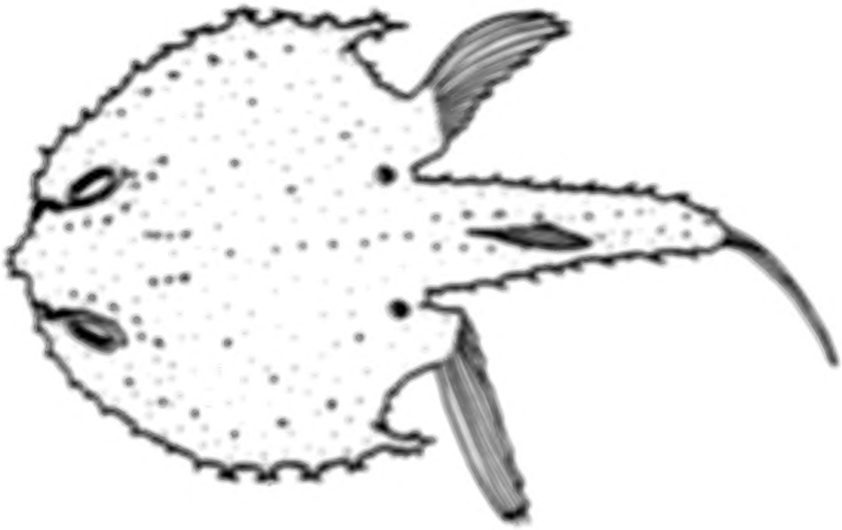


Figure 4-108. Frequency histograms for carapace lengths of Stereomastis sculpta from individual cruises.

unimodal curve. No obvious seasonal trends were evident (Fig. 4-108). There was a positive linear correlation ($r = 0.97$) between the logs of specimen width and weight (Fig. 4-106B). Mean weight was 10.5 g, within a range of 0.7 and 54 g.

4.3.5 FISH SPECIES ACCOUNTS

4.3.5.1 *Dibranchus atlanticus*



The batfish, *Dibranchious atlanticus*, occurs in the eastern and western Atlantic and is the only member of the genus that has been reported in the western North Atlantic (Bradbury 1967, 1977). In the northern and central Gulf of Mexico, Bright (1968) collected this species from 165-869 m in conjunction with temperatures of 10.9-9.3°C. Rayburn (1975) extended the maximum depth to 1353 m and reported that the greatest concentrations of *D. atlanticus* occurred from 360-500 m.

D. atlanticus was the most abundant fish species collected during this project. During Cruises II-V, a total of 575 specimens were taken in 32 trawls at 29 stations (Fig. 4-109). Based on the average depth of each trawl, *D. atlanticus* were collected at depths ranging from 351-964 m. Temperatures at these depths ranged from 10.6-5.1°C (extrapolated from nearest hydrographic stations).

This species was most abundant at depths ranging from 423-871 m. The 27 trawls (46% of total) made outside of this depth range accounted for only 1.4% (n = 8) of all specimens collected. This trend was consistent among transects and cruises. Depth related abundance levels also varied in conjunction with fish size. The 549 specimens examined ranged in total length from 30-145 mm (mean = 77.7, S.E. = 1.3) (Fig. 4-110A). However,

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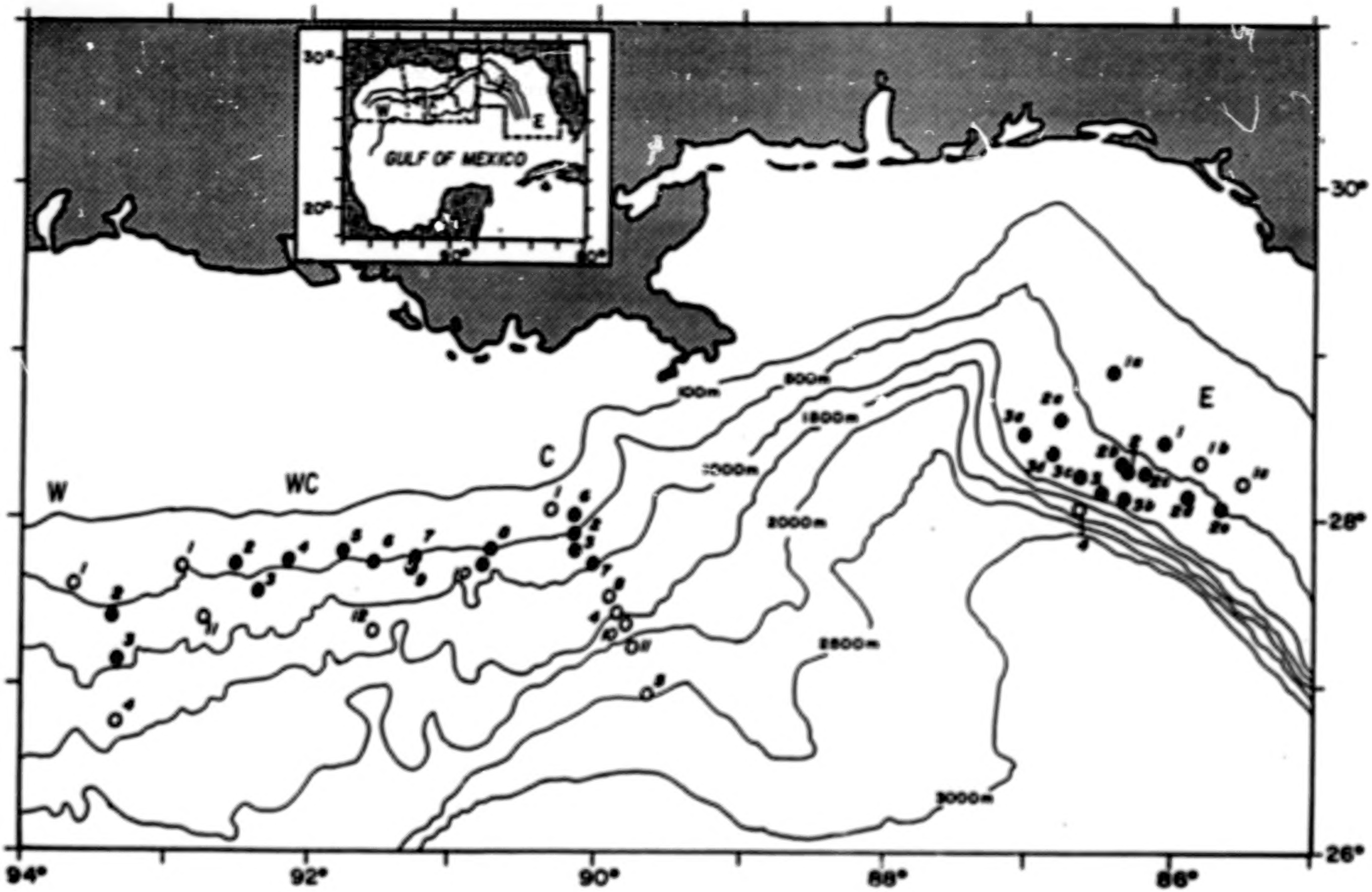
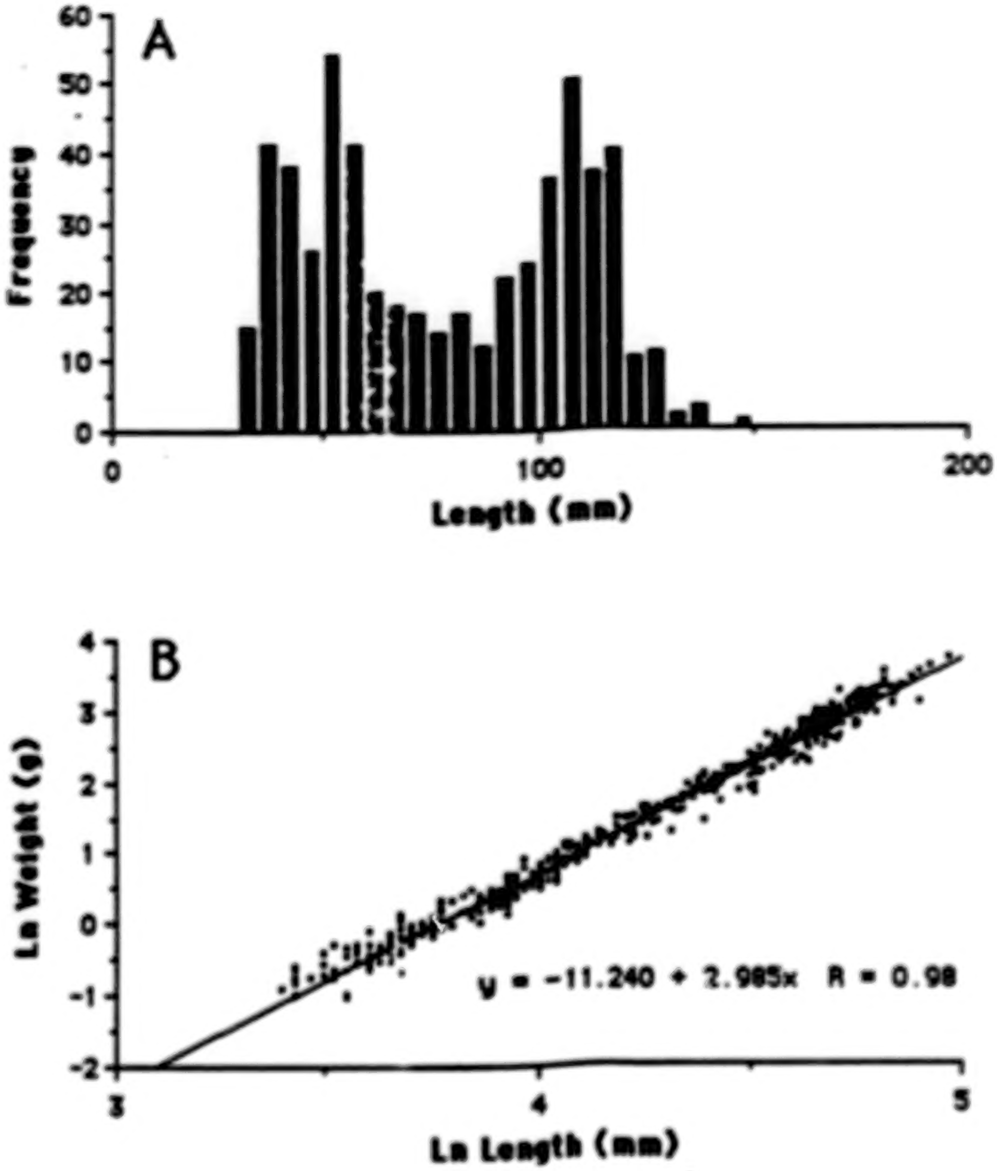


Figure 4-109. Locations where *Dibranchus atlanticus* were collected (closed circles).



Dibranchus atlanticus

Figure 4-110. Frequency histogram (A) and size-weight relationship (B) for total lengths of Dibranchus atlanticus (all stations pooled).

specimens measuring <90 mm total length occurred at depths ranging from 603-663 m (Fig. 4-111), whereas the majority of fish >90 mm were taken at depths of 802-871 m (Cruises II, III and IV) and 423-479 m (Cruise V) (Fig. 4-111). The influence of depth and fish size coupled with disproportionate sampling efforts (by depth and among cruises) obscured any geographic and yearly distinctions in abundance levels.

The ln length/ln weight relationship for D. atlanticus was linear ($y = 11.240 + 2.985x$, $r = 0.98$) across the entire length spectrum (40-149 mm) and indicates a uniform exponential increase in condition for all size cohorts (Fig. 4-110B).

D. atlanticus was the most opportunistic feeder of all the species examined. Thirty-three stomachs taken from the Western, Central and Eastern Transects contained a total of 19 identifiable prey items. Amphipods, polychaetes, isopods and cumaceans were the most frequently occurring food items; however, paguroidea, brachyura and thecosomata were also dominant in terms of weight and volume (Fig. 4-112). Comparisons of small (< median fish weight) and large (> median fish weight) individuals indicated size related differences in feeding habits. In terms of frequency of occurrence, small fish showed a greater preference for isopods (40.0% vs 5.6%) and pycnogonids (20% vs 2%).

Rayburn (1975) examined D. atlanticus taken from the northern Gulf of Mexico and found that bivalves (43%), gammarid amphipods (26%), and ostracods (22%) were the most frequently occurring of 17 food items. The difference in results is undoubtedly due, in part, to size related feeding habits and trophic diversity exhibited by this species.

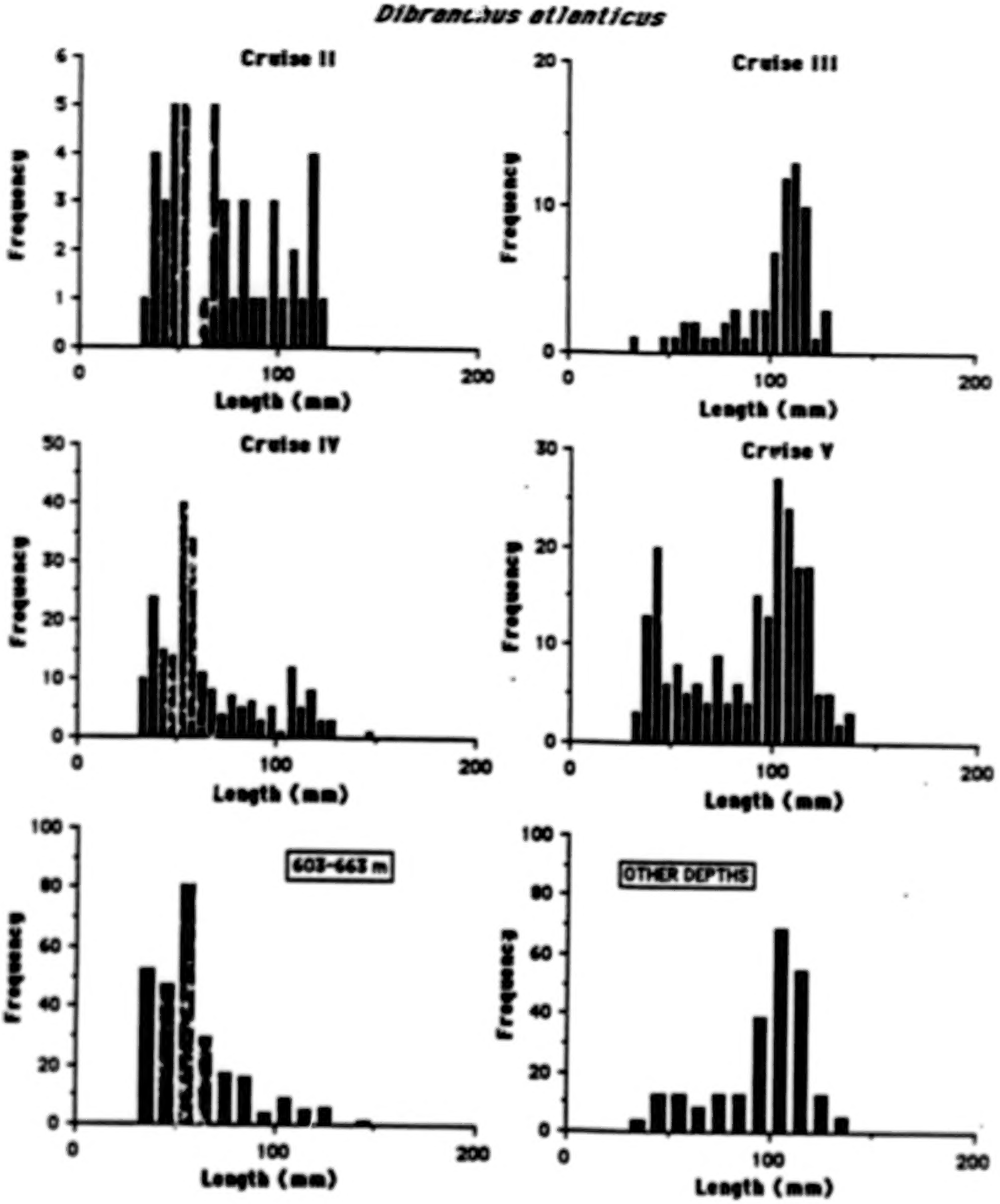


Figure 4-111. Frequency histograms for total lengths of Dibranchus atlanticus from individual cruises.

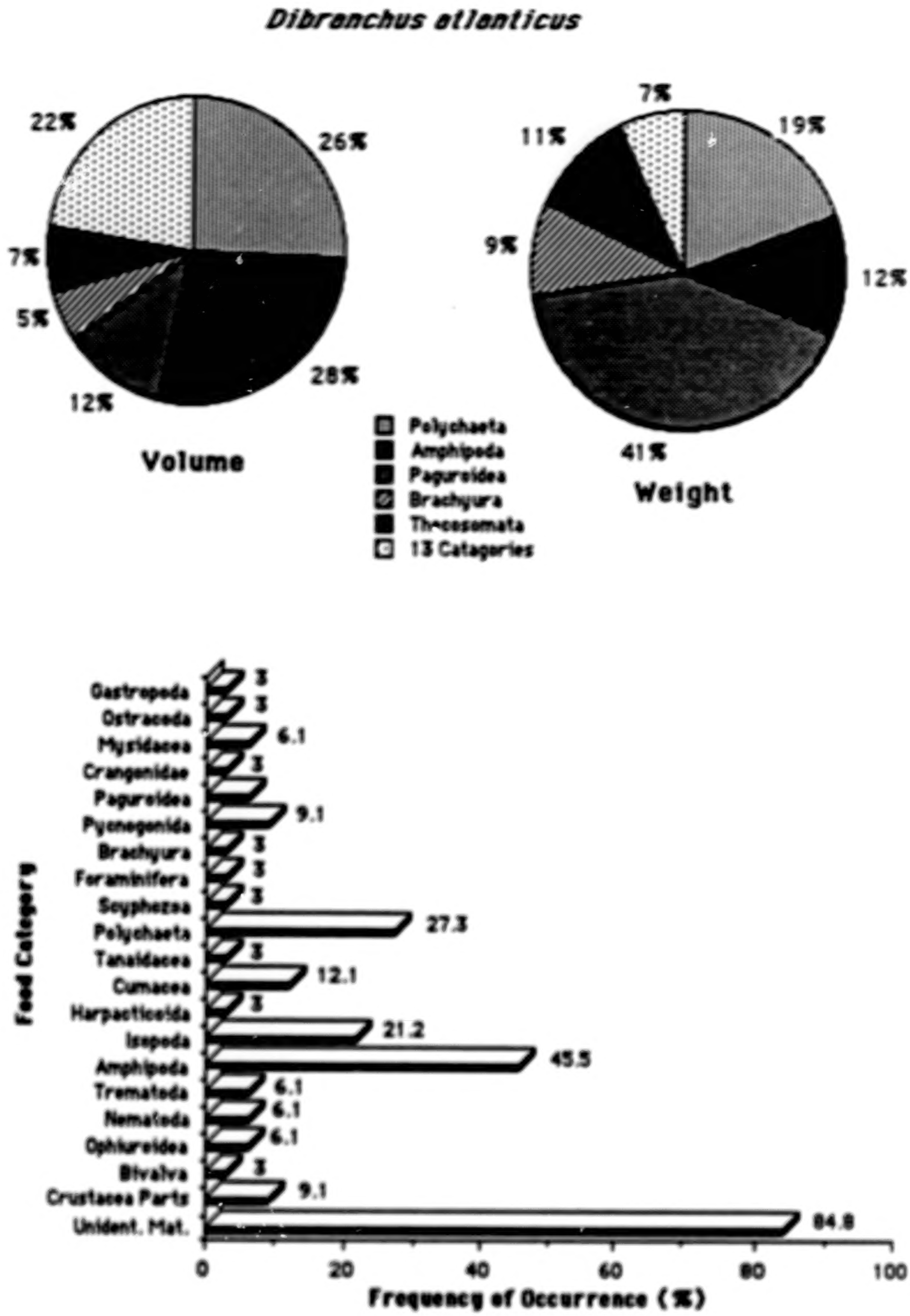
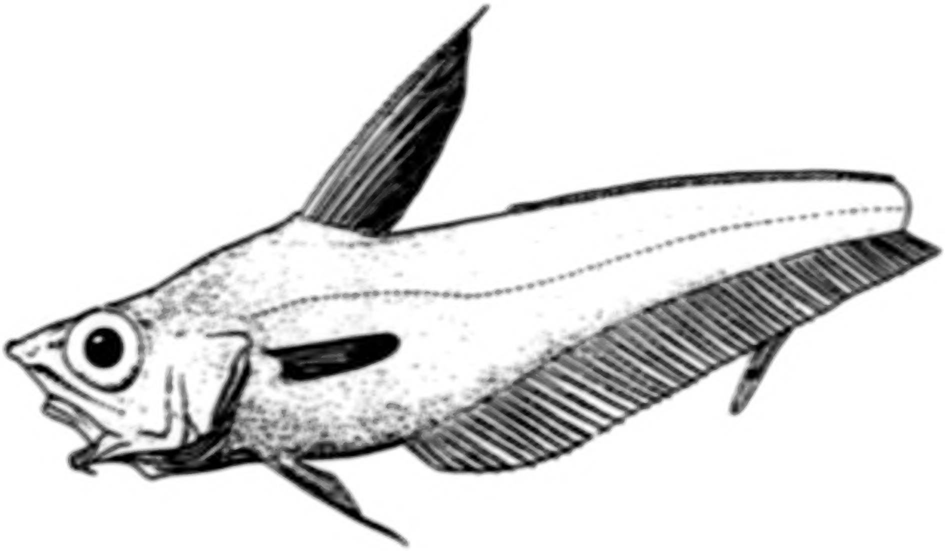


Figure 4-112. Stomach contents found in Dibranchus atlanticus plotted by volume and weight (upper) and by percent frequency of occurrence.

4.3.5.2 Nezumia aequalis



The smooth grenidier, Nezumia aequalis, is found in the eastern Atlantic from Faroe Bank to northern Angola and into the Mediterranean, and in the western Atlantic from Davis Straights to northern Brazil and through the Gulf of Mexico. Its bathymetric range has been listed as 200-1000 m (Marshall and Iwamato 1973). Recent collections in the Norfolk Canyon off Virginia found N. aequalis at depths of 367-1109 and in temperatures of 4.3-8.0°C (Middleton and Musick 1986).

A total of 236 N. aequalis was collected in 26 trawls and at 20 stations during all five cruises of this project (Fig. 4-113). Specimens were collected over a relatively wide bathymetric range (474-871 m), based upon average depth of trawl. Relative abundances of this species indicated no obvious center of distribution either by depth or by geographic region within the Gulf.

Head lengths for the 201 specimens measured during this project ranged from 14-45 mm (mean = 35.6 mm, S.E. = 0.4 mm; Fig. 4-114A). The length-frequency distribution was modal at 36-38 mm and skewed toward the higher end of the length spectrum. These results are biased in favor of Cruise IV catches since they constituted 65% of the total sample size (Fig. 4-115).

Middleton and Musick (1986) found a positive correlation between size and depth-distribution for N. aequalis collected on the east coast of the

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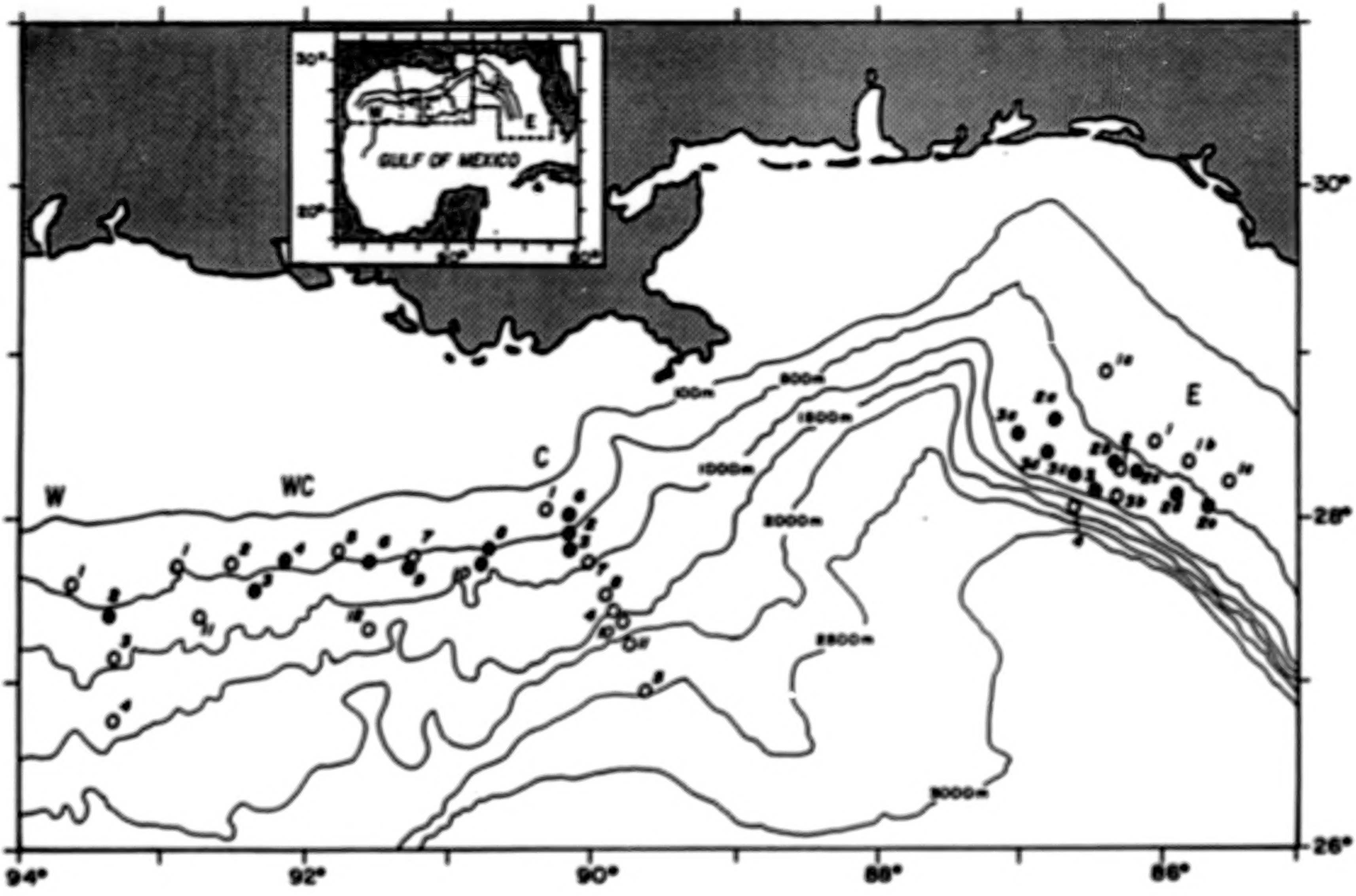


Figure 4-113. Locations where Nezumia aequalis were collected (closed circles).

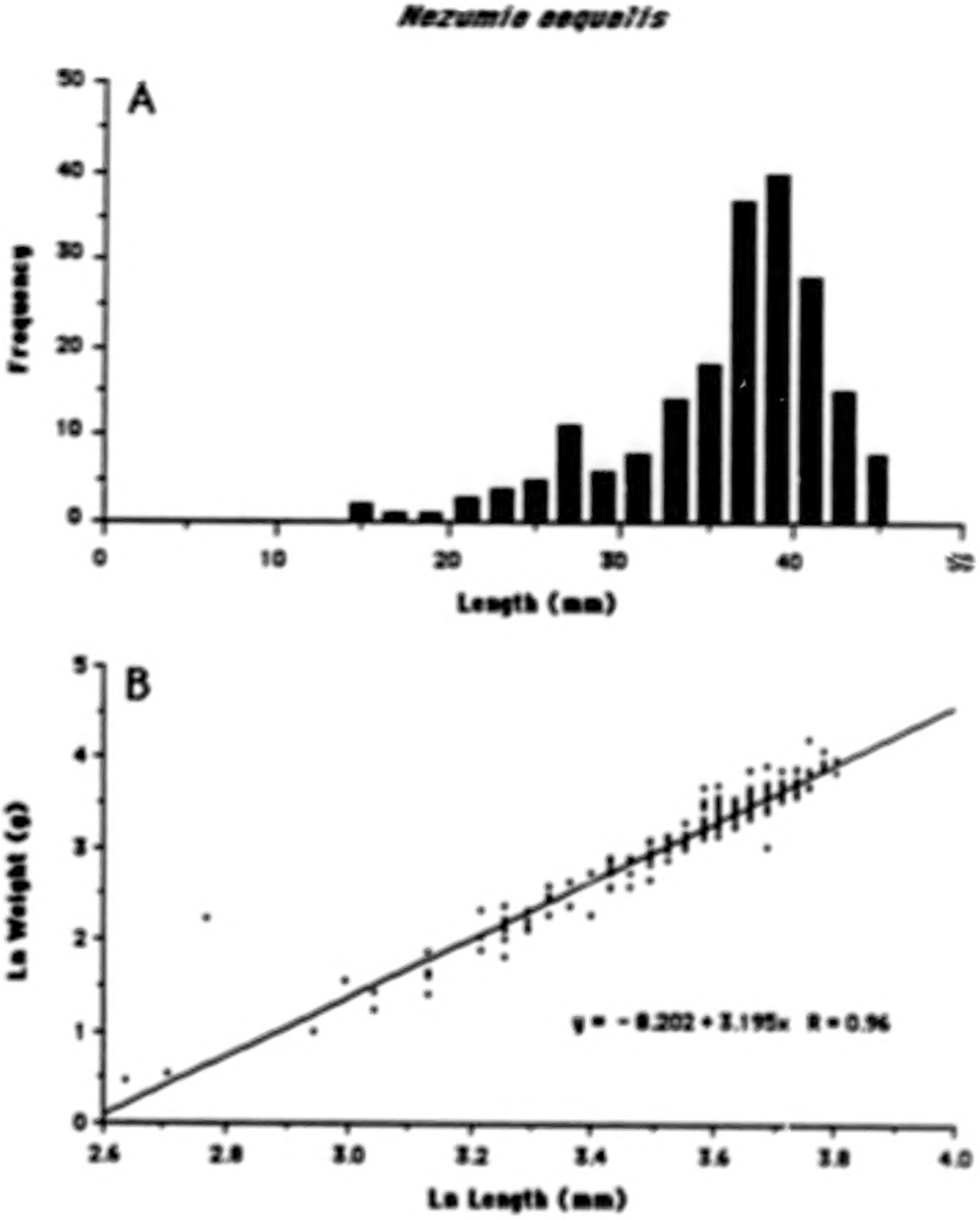


Figure 4-114. Frequency histogram (A) and size-weight relationship (B) for total lengths of *Nezumia aequalis* (all stations pooled).

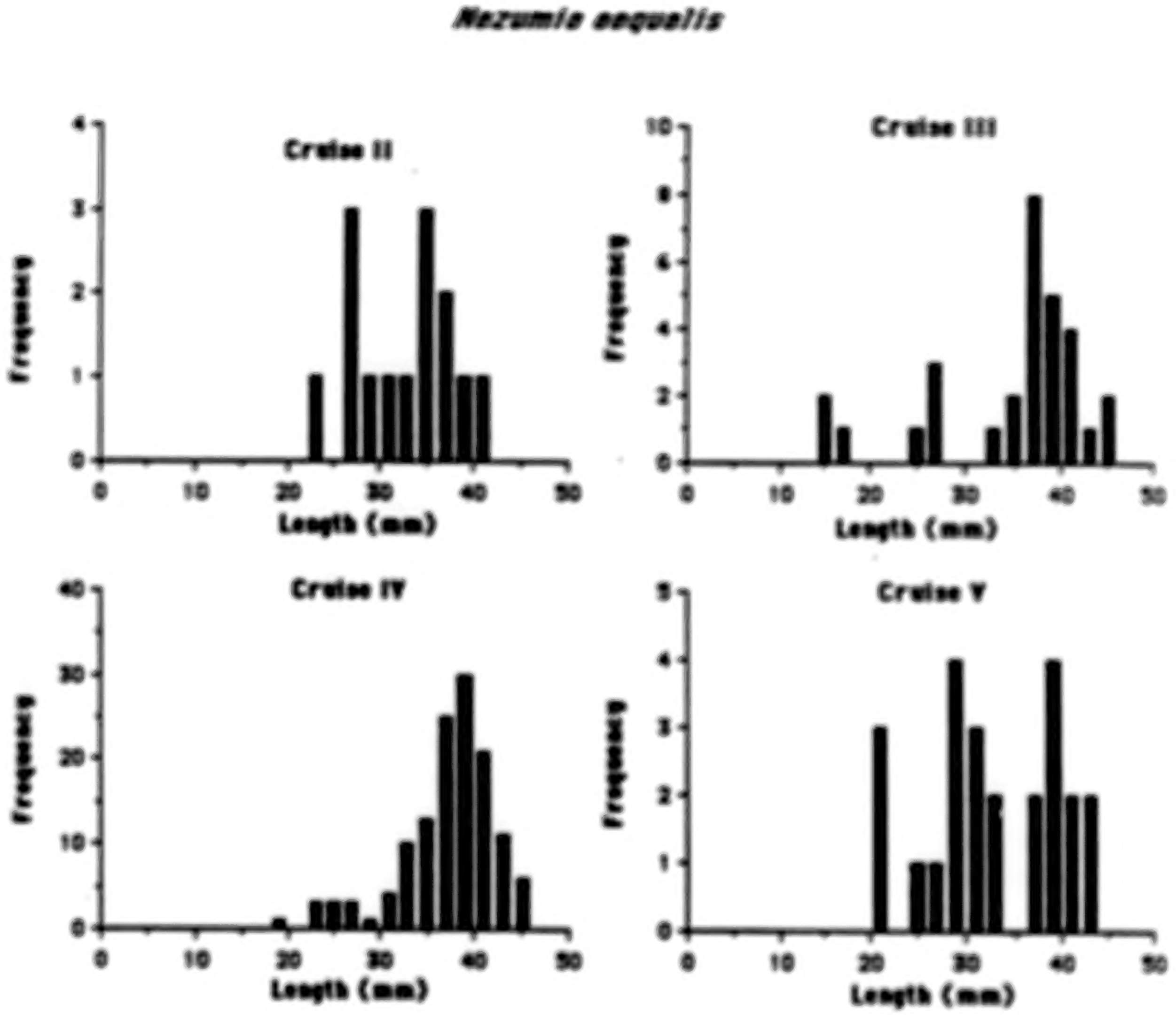


Figure 4-113. Frequency histograms for total lengths of Nezumia aequalis from individual cruises.

United States. For fish collected at depths of 600-700 m and 800-900 m, mean head lengths were 35.0 and 39.0 mm, respectively. These data are consistent with the findings of Middleton and Musick (1986). However, while larger fish (>40 mm) were found at both depth ranges, few small fish (<35 mm) were caught at 800-900 m stations.

Only thirteen stomachs of *N. aequalis* were examined, all of which contained some prey items. Natantia was the most important of the nine identifiable food categories taken in terms of volume, weight and frequency of occurrence (Fig. 4-116). Amphipoda was the only other major food item by volume and weight while calanoid copepods and tanaidaceans represented major food items based upon frequency of occurrence.

Rayburn (1975) also examined the diets of *N. aequalis* collected in the Gulf of Mexico. Based upon frequency of occurrence, he found polychaetes (88%) to be the most important food item followed by gammarid amphipods (60%), tanadacians (40%), ostracods (36%) and cumaceans (30%).

More recently, Mauchline and Gordan (1984) performed detailed trophic analysis on *N. aequalis* collected in the northeastern Atlantic. Based upon the examination of 1013 individuals, they found amphipods to be the dominant food item by volume (50-60%) and by frequency of occurrence (80%). Calanoid copepods, mysids, polychaetes, isopods, decapods and brittle stars also contributed substantially to the diet. They concluded that *N. aequalis* consumed a wide variety of food items, all of which were organisms closely associated with sediment surface.

The ln transformed length/weight regression yielded a strong linear relationship ($y = 8.202 + 3.195x$, $r = 0.96$), indicating a uniform exponential increase in condition factor with increasing length (Fig. 4-114B).

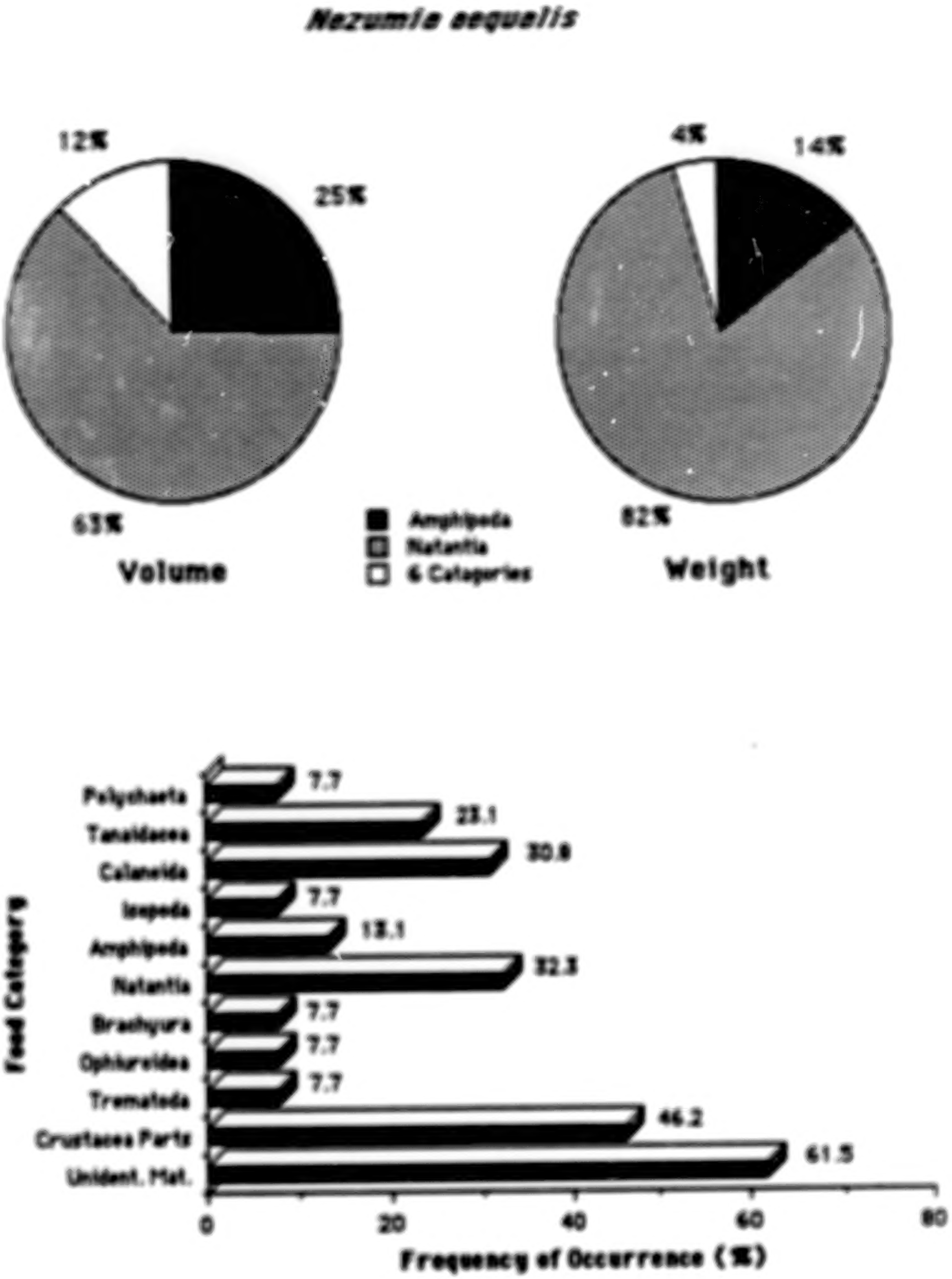
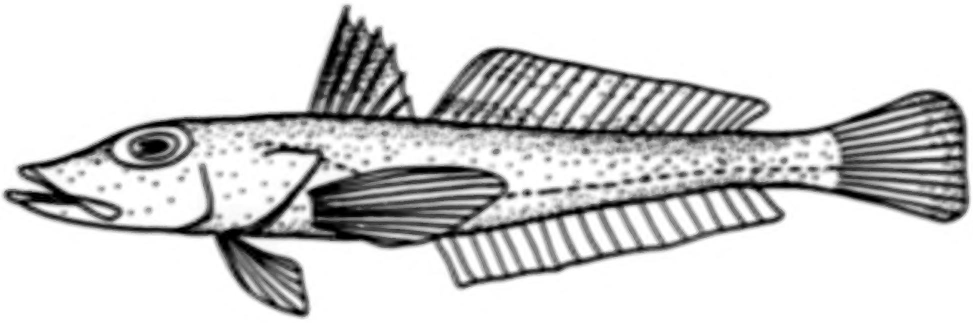


Figure 4-116. Stomach contents found in Nezumia aequalis plotted by volume and weight (upper) and by percent frequency of occurrence.

4.3.5.3 Bembrops gobioides



The percophid, Bembrops gobioides, occurs in the western North Atlantic from New York to Florida, throughout the Caribbean and in the northern Gulf of Mexico. Its depth distribution ranges from 148-594 m with corresponding temperatures of 14.4-8.6°C (Bright 1968).

B. gobioides was the third most abundant fish species collected during this project. A total of 366 specimens were caught in 15 trawls at 13 stations during Cruises II-V (Fig. 4-117). Based on ave[illegible] depth of trawl, B. gobioides were collected primarily between 338-551 m. The 42 trawls (72% of total) made below 511 m resulted in the capture of one specimen. With the exception of Cruise I, all trawls made within the 338-551 m depth range resulted in the capture of B. gobioides regardless of transect or cruise.

Specimens of B. gobioides ranged in total length from 70-262 mm (mean = 190.4, S.E. = 2.4) (Fig. 4-118A). The dominant size cohort during Cruises II, IV and V was around 200-240 mm (Fig. 4-119). The small sample size (n = 10) obtained during Cruise III prevented interpretation of length-frequency data. Multimodal distributions indicated the presence of additional size cohorts at 100-120 mm, 160-170 mm and possibly 180-200 mm. We found no clear distinctions in depth distribution based upon fish size.

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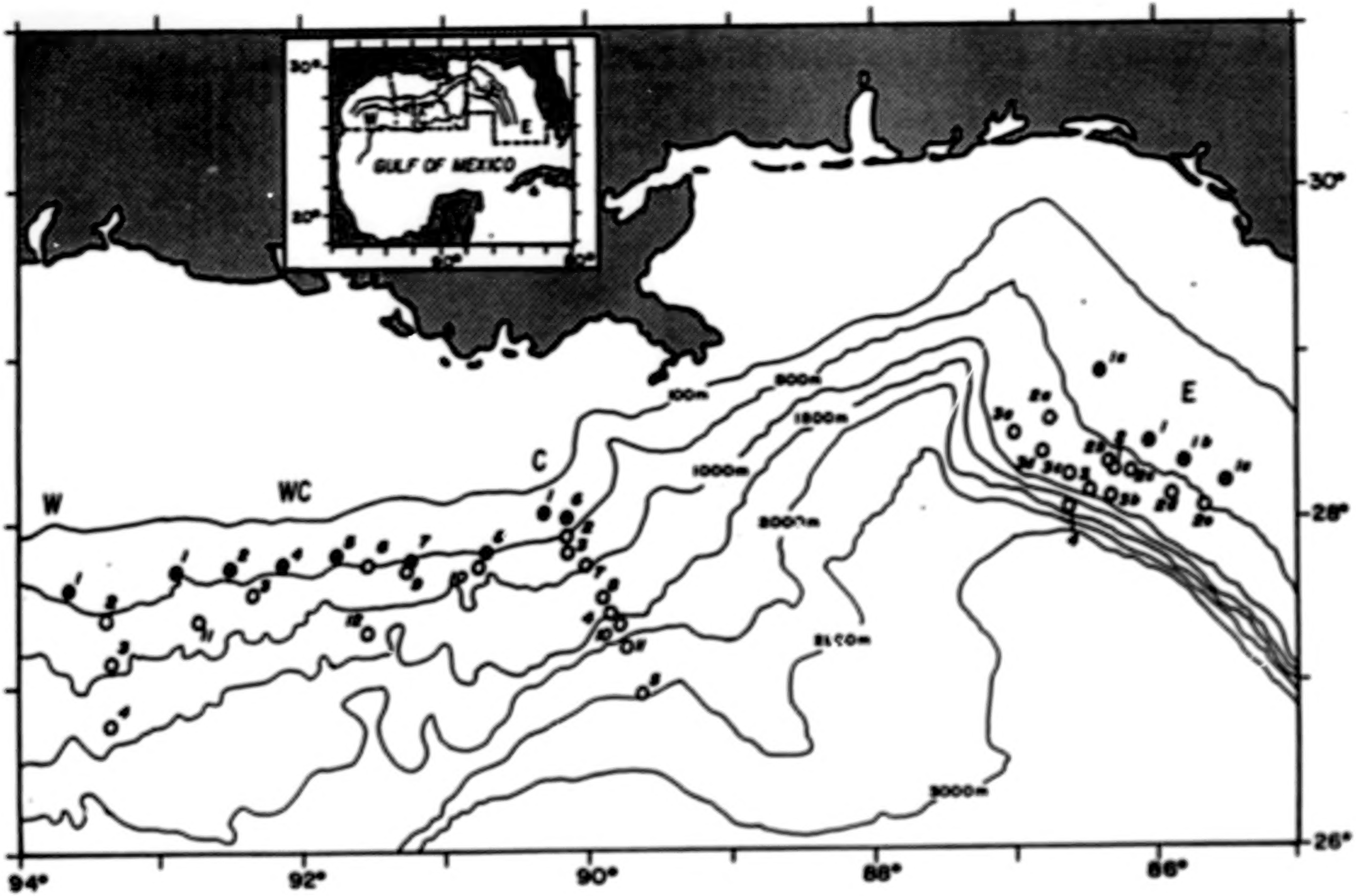

Figure 4-117. Locations where Bembrops gobioides were collected (closed circles).

Bembrops gobioides

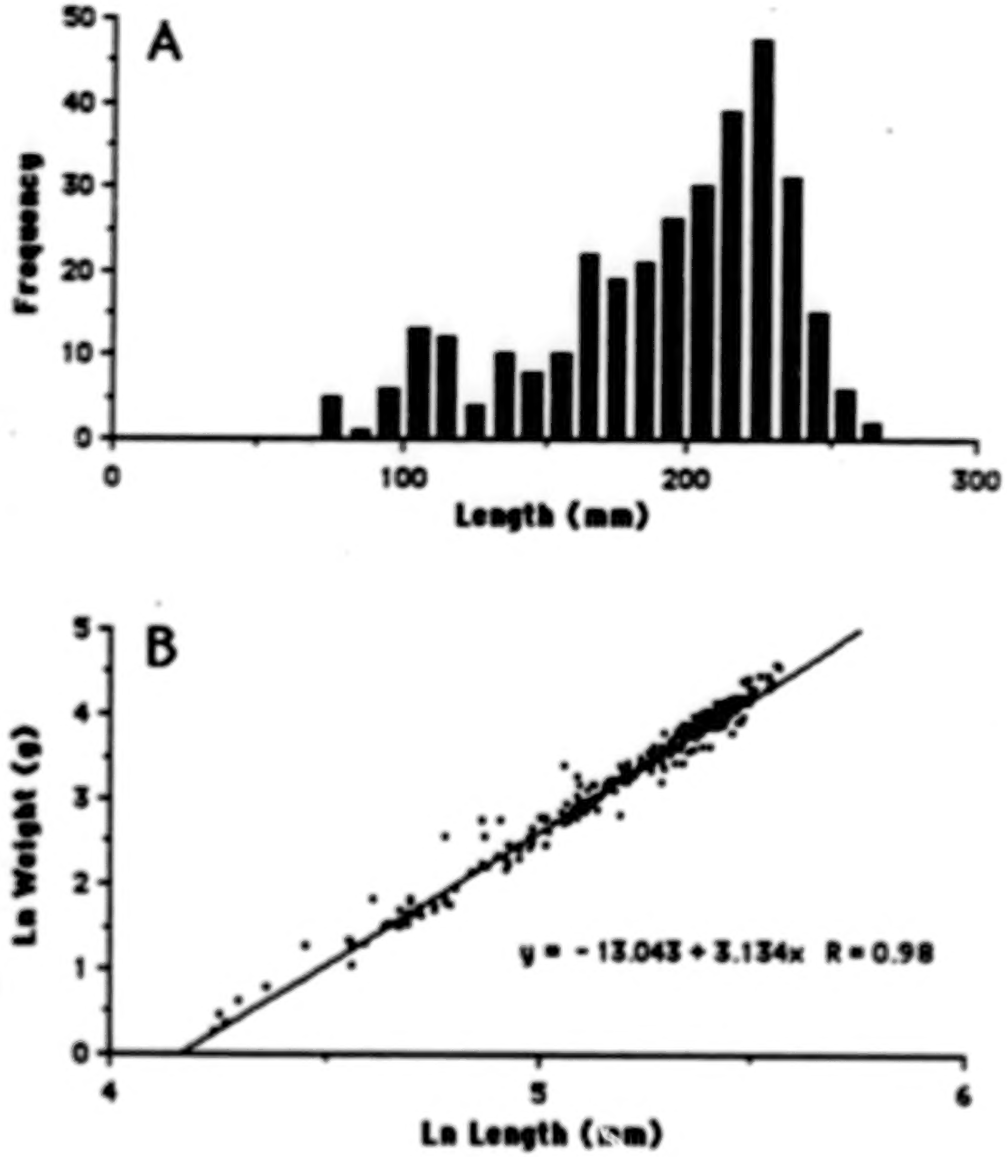

Figure 4-118. Frequency histogram (A) and size-weight relationship (B) for total lengths of *Bembrops gobioides* (all stations pooled).

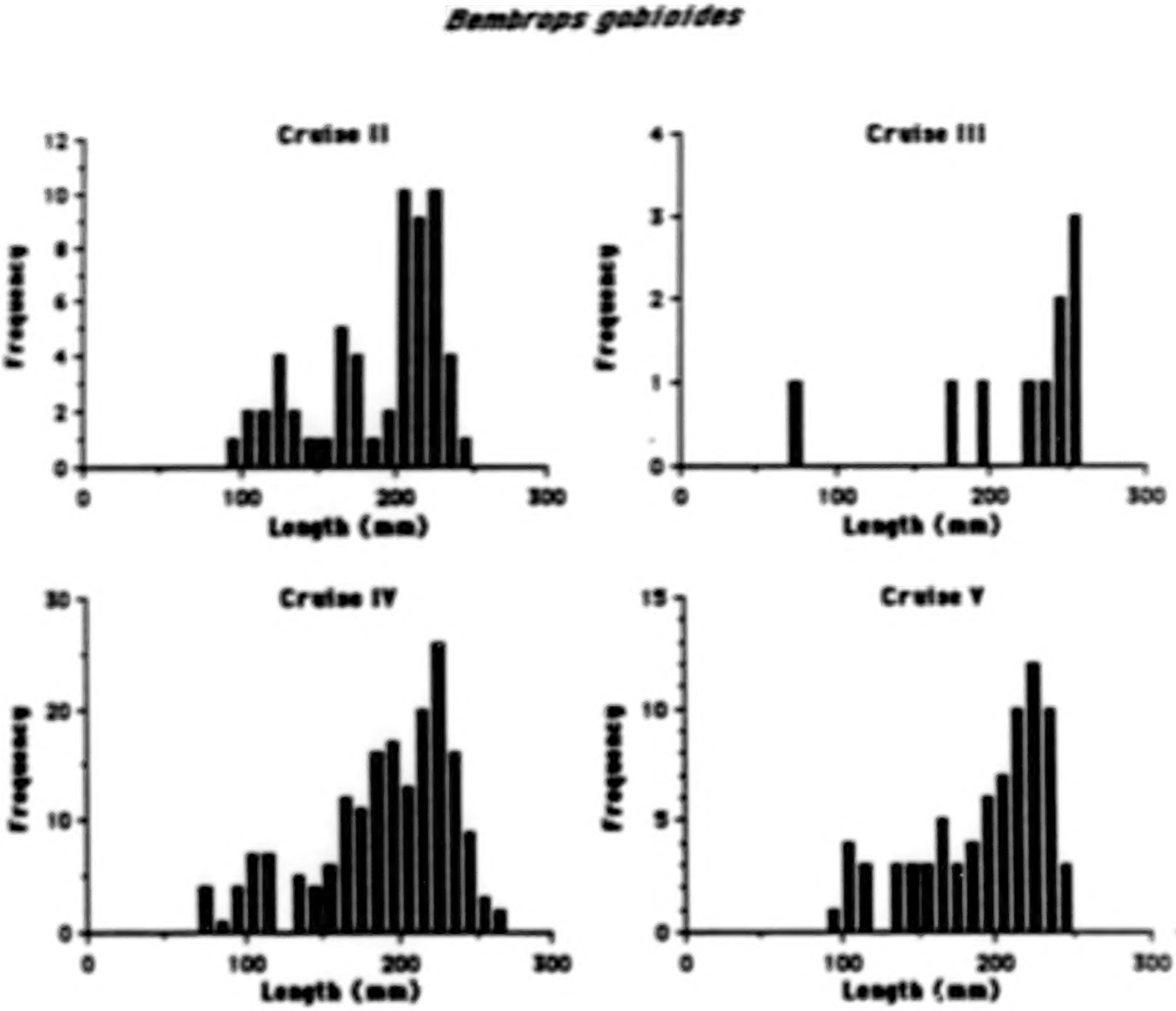

Figure 4-119. Frequency histograms for total lengths of Bembrops gobioides from individual cruises.

The ln length/ln weight relationship (Fig. 4-118B) for all specimens combined was linear ($y = -13.043 + 3.134x$, $r = 0.98$) indicating a uniform increase in condition across size cohorts (70-262 mm).

B. gobioides appears to be an active predator that feeds primarily on large nektonic organisms. Seventeen of the 30 stomachs taken from fish collected in the Eastern, Central and Western Transects contained only three identifiable organisms: Nantantia, Osteichtys and Foraminifera. Nantantia was the most abundant food item in terms of weight, volume and frequency of occurrence (Fig. 4-120). Because the dominant prey items are large motile organisms, it is likely that Foraminifera were consumed incidentally. Bright (1968) examined three specimens of B. gobioides and reported similar results. In addition to the predominance of large macruran decapods, he also found one gammarid amphipod, one calinoid copepod and one mysid.

Comparison of stomach contents between small (< median fish weight) and large (> median fish weight) individuals indicate similar diets with one exception. Six of the seven large individuals examined contained Nantantia while only two of the 10 small specimens contained this prey item.

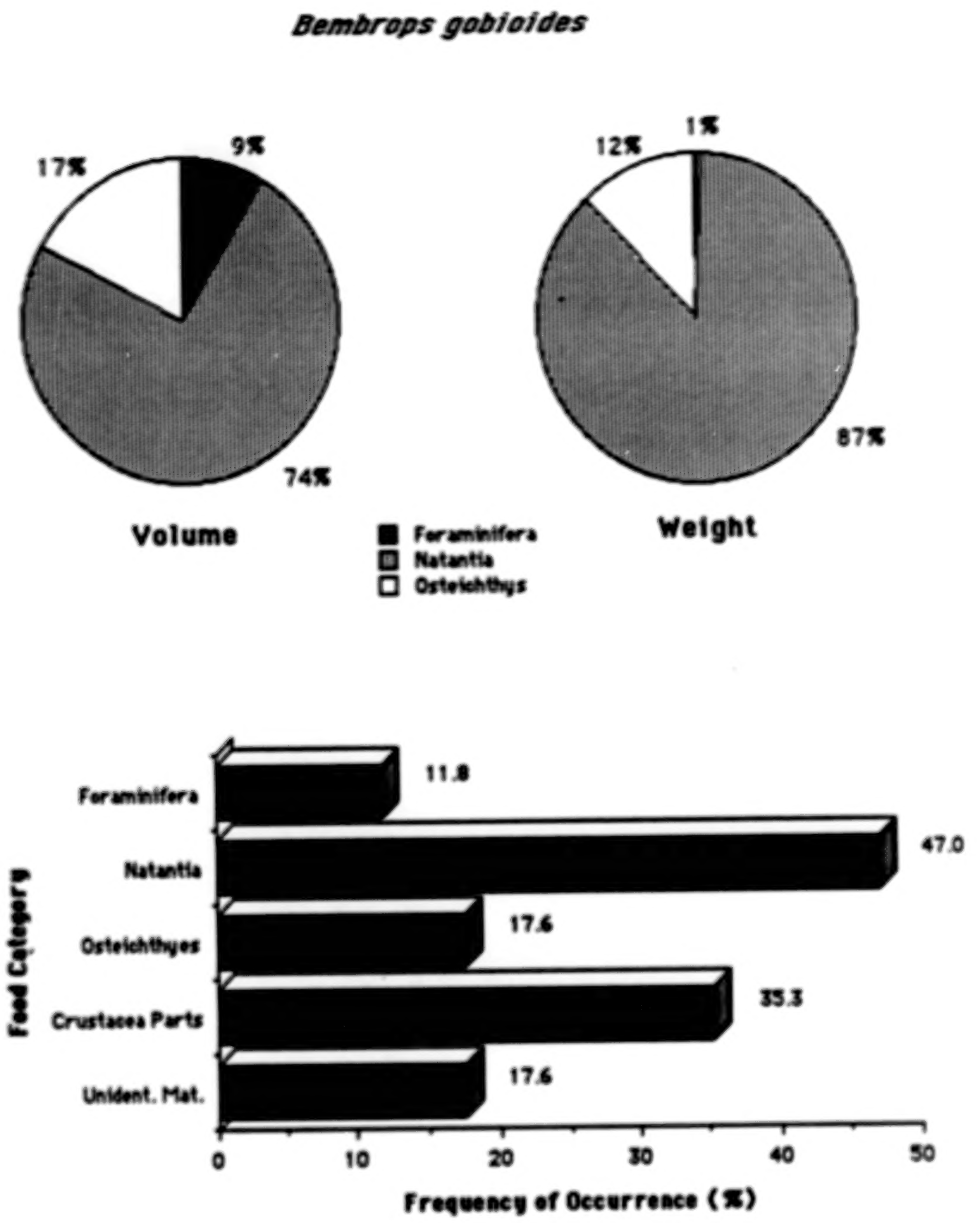

Figure 4-120. Stomach contents found in Bembrops gobioides plotted by volume and weight (upper) and by percent frequency of occurrence.

4.3.5.4 Coelorinchus caribbaeus

Coelorinchus caribbaeus is a shallow water grenidier found in the western North Atlantic from Virginia (Middleton and Musick 1968) to northeastern South American waters and throughout the Caribbean and Gulf of Mexico. Its depth range is listed at 183-732 m with populations apparently centered between 329-412 m (Marshall and Iwamoto 1973).

C. caribbaeus was collected during all five cruises but the 177 individuals were taken in only eight trawls at six stations (Fig. 4-121). The most productive station was C1 where specimens were taken on all three sampling occasions (Cruises I, II, III). This station accounted for 71% (n = 125) of all C. caribbaeus caught during this project. The other five stations were C2 (n = 1), W1 (n = 3), 1A (n = 20), WC1 (n = 10), and WC5 (n = 12). Except for Stations C2 (786 m) and WC5 (423 m), all fish were collected within a narrow depth range of 329-368 m. This bathymetric range overlaps well with that reported by Marshall and Iwamato (1973). C. caribbaeus was not present in all areas based upon trawl depth. The average trawl depths at Stations E1, 1, 1B, and 1C were between 345-366 m, yet no specimens were taken.

The 124 specimens of C. caribbaeus examined ranged in head length from 25-72 mm (mean = 54.2, S.E. = 1.0) (Fig. 4-122A). For each of the five cruises there was a dominant size cohort in the 55-65 mm area (Fig. 4-123). The only signs of a distinct multimodal distribution was during

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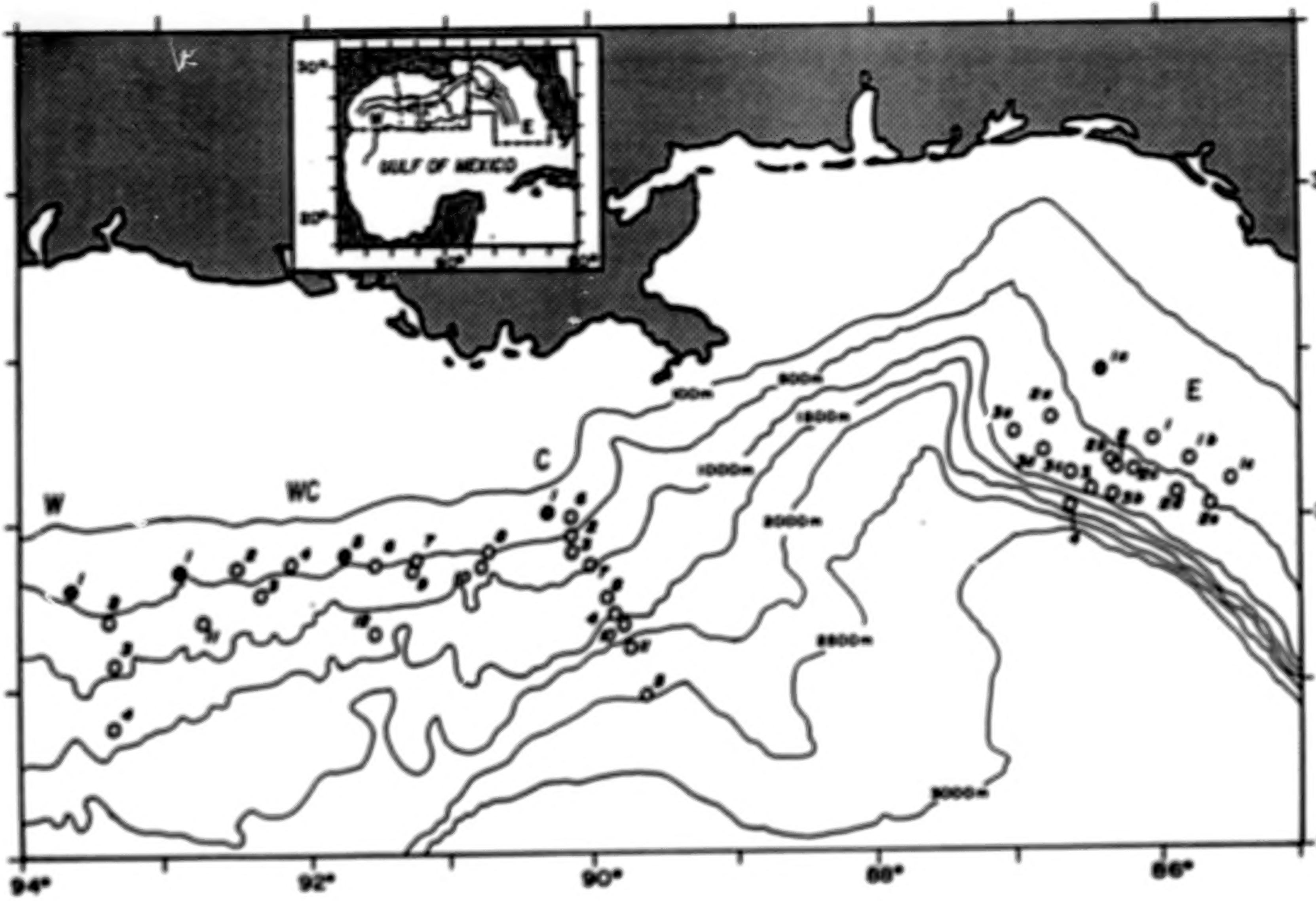


Figure 4-121. Locations where *Coelorinchus caribbaeus* were collected (closed circles).

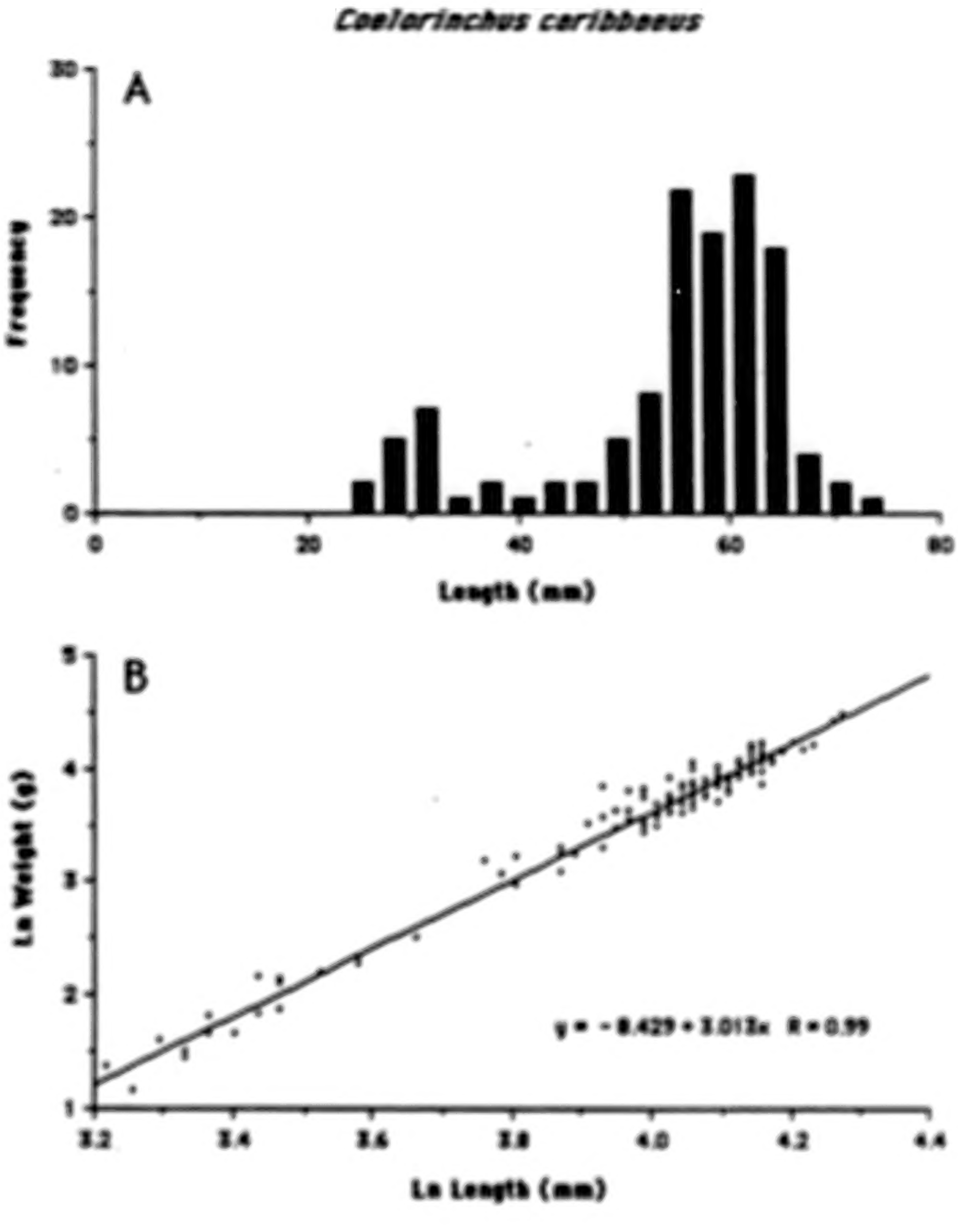


Figure 4-122. Frequency histogram (A) and size-weight relationship (B) for total lengths of Coelorinchus caribbaeus (all stations pooled).

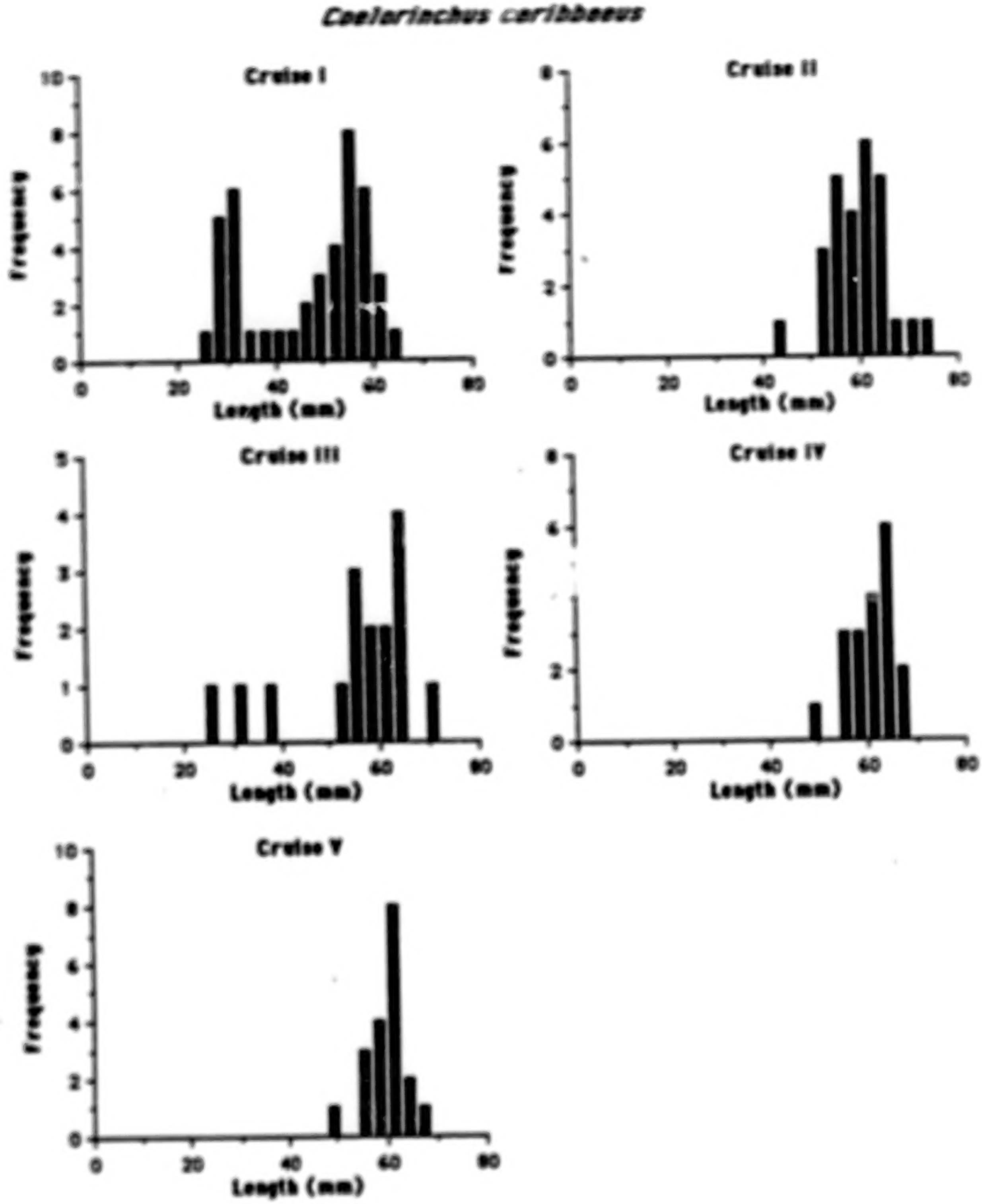


Figure 4-123. Frequency histograms for total lengths of Coelorinchus caribbaeus from individual cruises.

Cruise I in which there was a secondary size aggregation at about 30 mm.

The ln length/ln weight relationship was linear ($y = 8.429 + 3.013x$, $r = 0.99$) throughout the entire length spectrum (25-72 mm) and indicated a uniform exponential increase in condition across at least two size cohorts (Fig. 4-122B).

All 15 stomachs examined came from collections at Station C1. Fourteen identifiable food items were taken by this species, indicating that it exploits a wide array of prey (Fig. 4-124). Polychaeta was the most important food category by volume and weight but ranked third behind Amphipoda and Calinoida in frequency of occurrence. While Natantia occurred in only 26.7% of the stomachs examined, it was the second most dominant food item by volume and weight (Fig. 4-124).

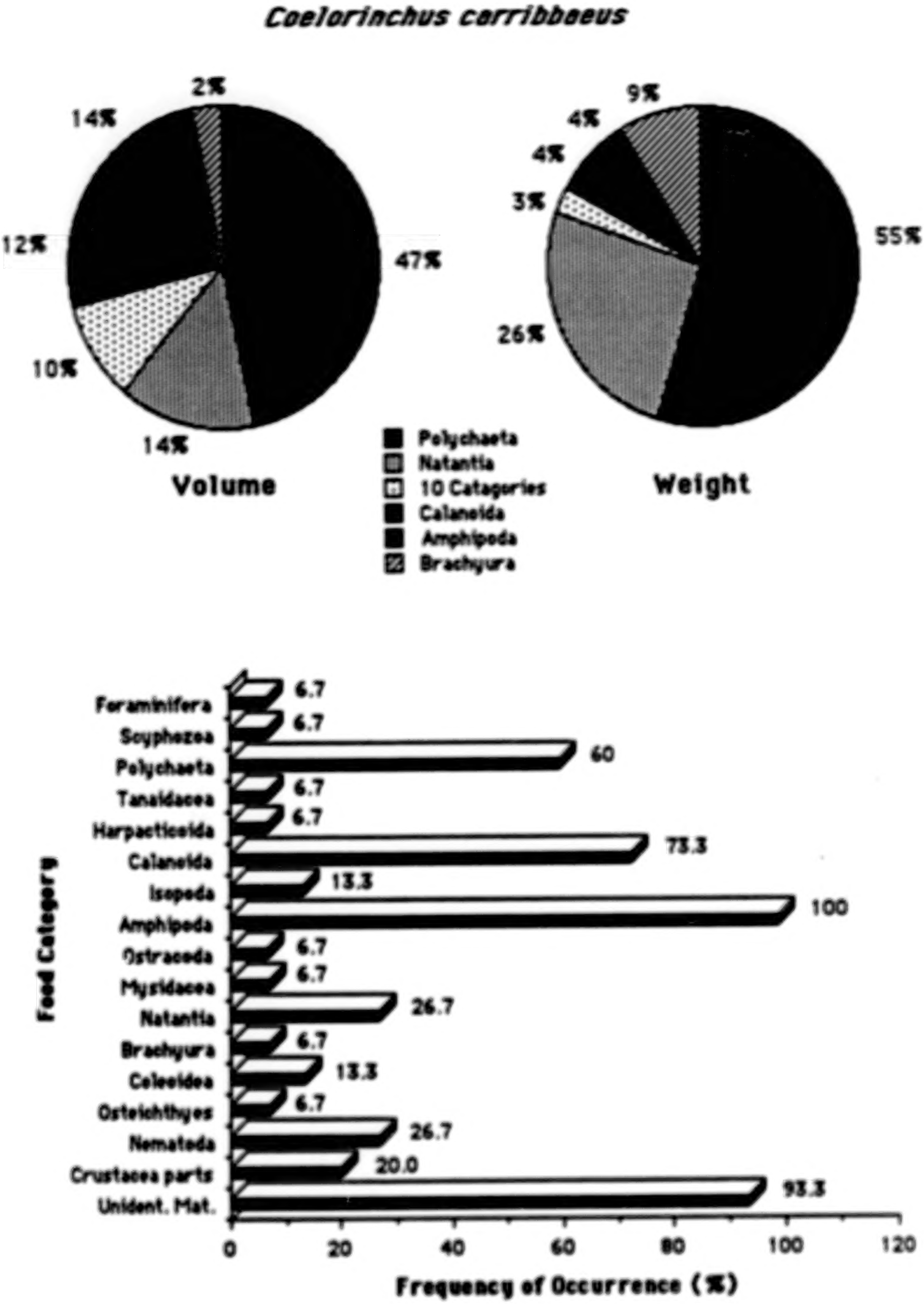
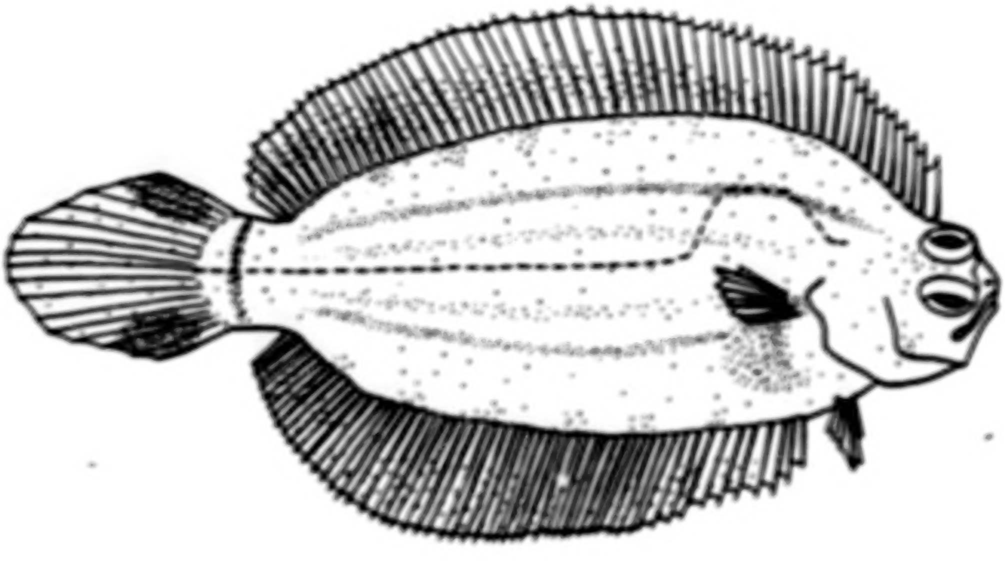


Figure 4-124. Stomach contents found in Coelorinchus caribbaeus plotted by volume and weight (upper) and by percent frequency of occurrence.

4.3.5.5 *Poecilopsetta beani*



The right-eyed flounder *Poecilopsetta beani* occurs in the western Atlantic from New England to northeastern South America and throughout the Caribbean and Gulf of Mexico. It has been reported over an extremely wide bathymetric range (53-1637 m) but is apparently most common between 180-550 m (Bright 1968).

P. beani was collected during every cruise in a total of 13 trawls at 11 stations (Fig. 4-125). Specimens were generally restricted to the shallowest areas sampled during this project. Of the 155 individuals taken, 93% (n = 142) were collected at depths ranging from 329-368 m. The only station that fell within this depth range and where no specimens were found was E1 (366 m).

P. beani ranged in total length from 40-122 mm for the 137 specimens examined (mean = 83.3, S.E. = 1.7) (Fig. 4-126A). The largest sample was collected during Cruise IV, and the length-frequency distribution indicates the presence of at least three size groups: a dominant mode at 50-60 mm and secondary modes at 85-90 mm and 105-110 mm (Fig. 4-127). Samples were considerably smaller for the remaining cruises but there was evidence of dominant size cohorts at 90-100 mm during Cruises I, II, and V (Fig. 4-126B).

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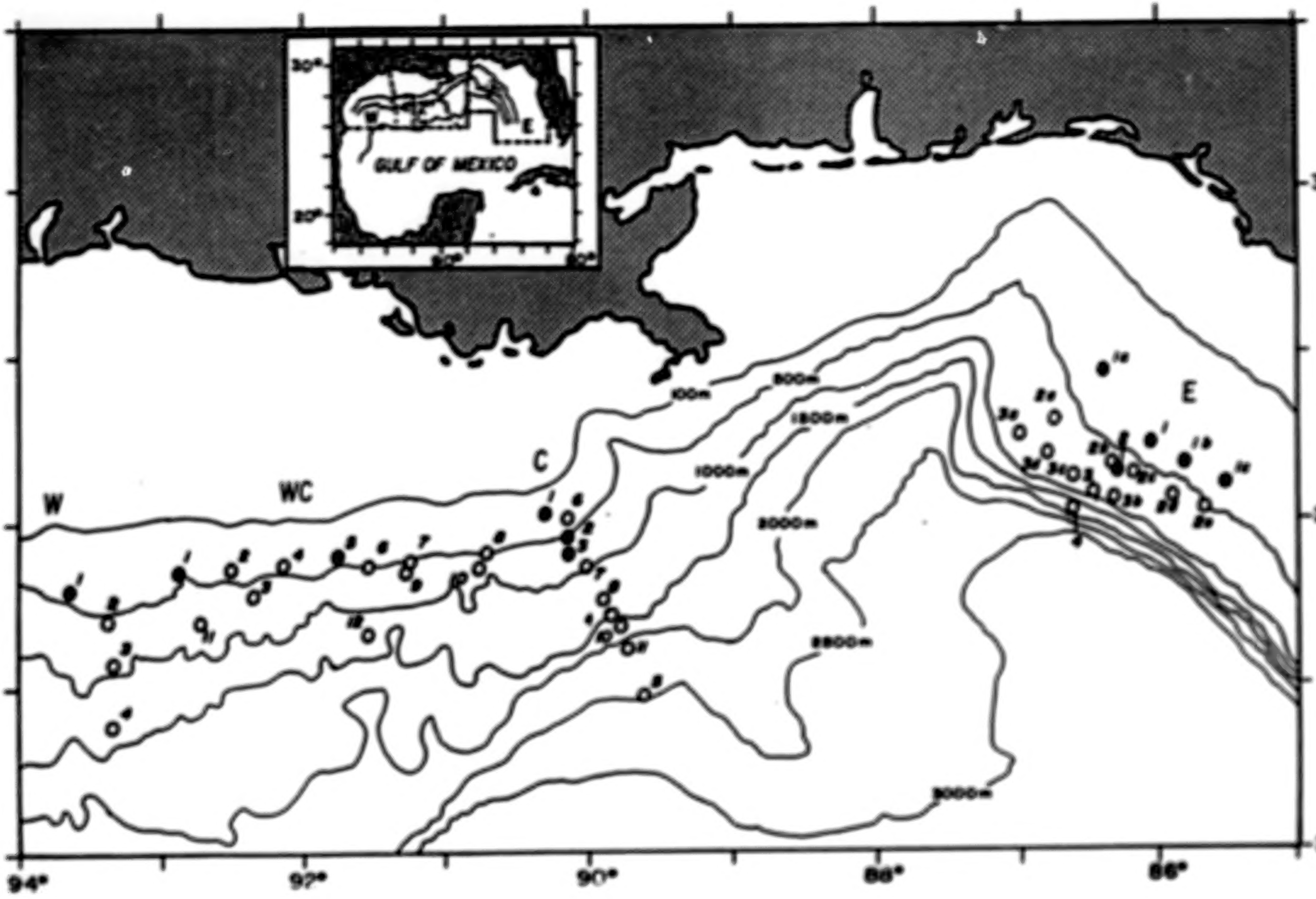


Figure 4-125. Locations where Poecilosetta beani were collected (closed circles).

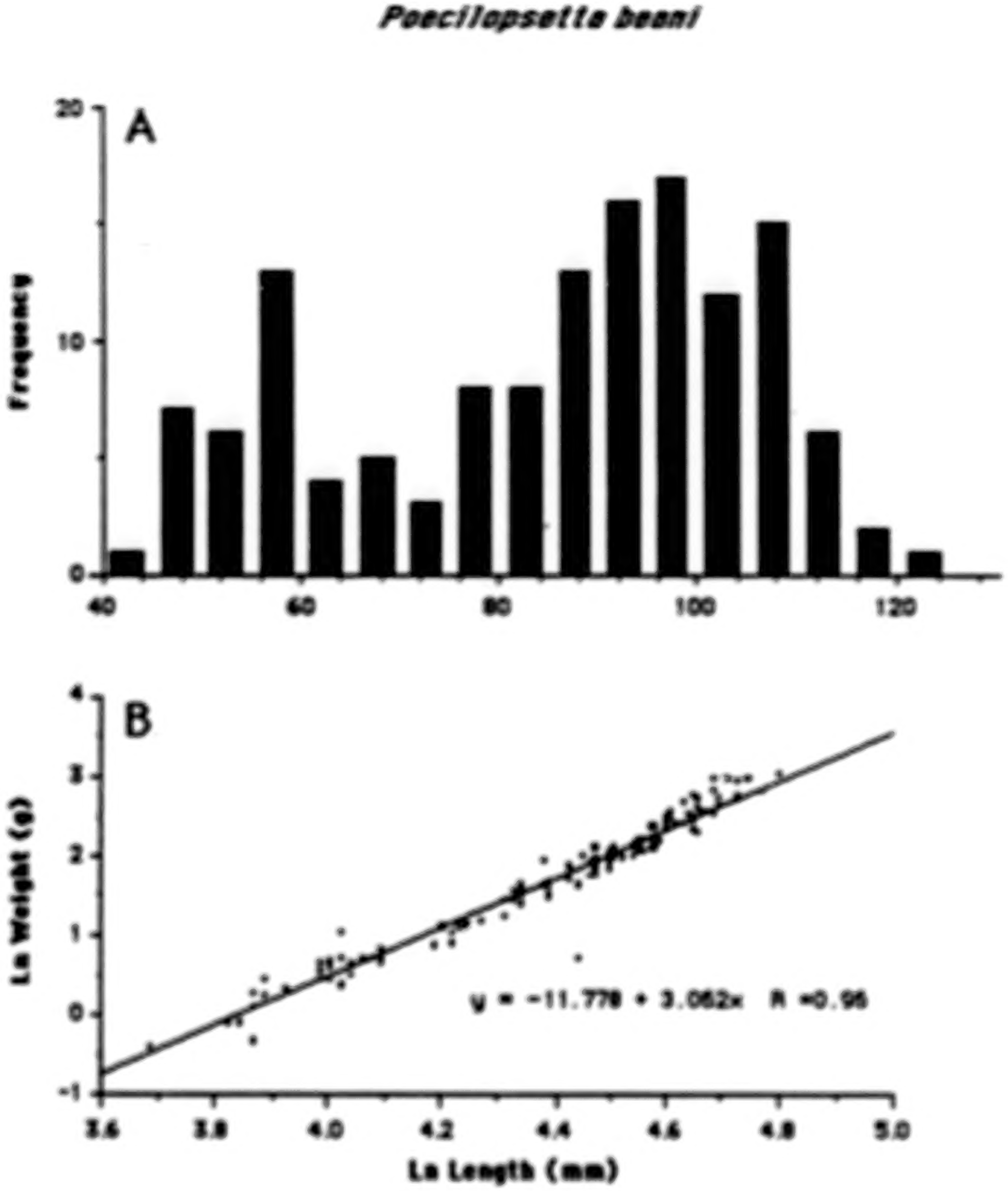


Figure 4-126. Frequency histogram (A) and size-weight relationship (B) for total lengths of Poecilosetta beani (all stations pooled).

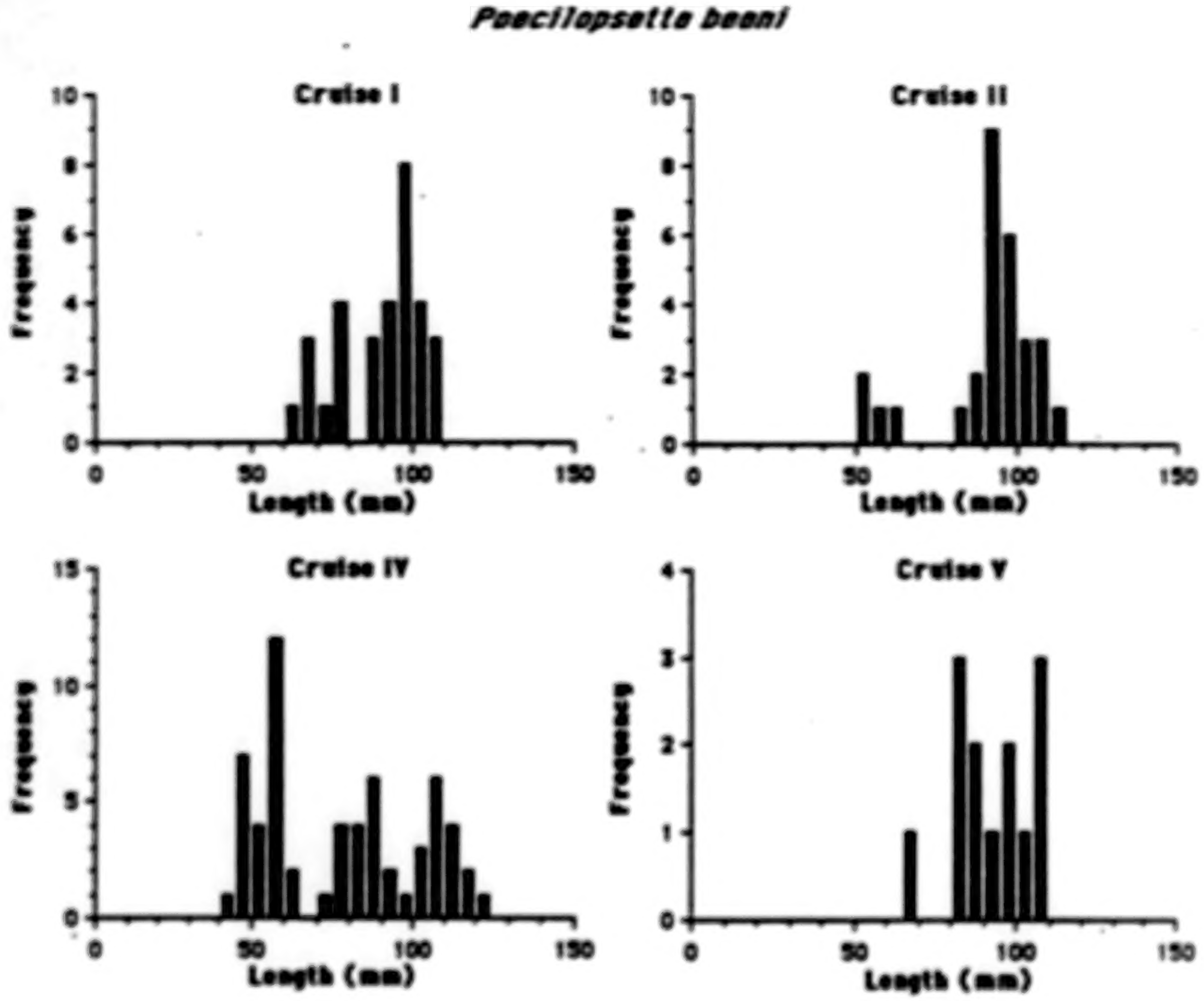


Figure 4-127. Frequency histograms for total lengths of Poecilosetta beani from individual cruises.

The ln transformed length/weight relationship was linear ($y = -11.778 + 3.062$, $r = 0.98$) for this species and indicates an exponential increase in condition for fish within the length range sampled (22-122 mm) (Fig. 4-126B).

Stomach analysis was performed on 21 specimens of *P. beani* collected from Stations W1 and C1; however, 12 of these were empty. Amphipods were the preferred prey item in terms of volume, weight (Fig. 4-128) and frequency of occurrence (Fig. 4-128). Calanoid copepods and mysids were also substantial dietary components with polychaetes being the only other identifiable item.

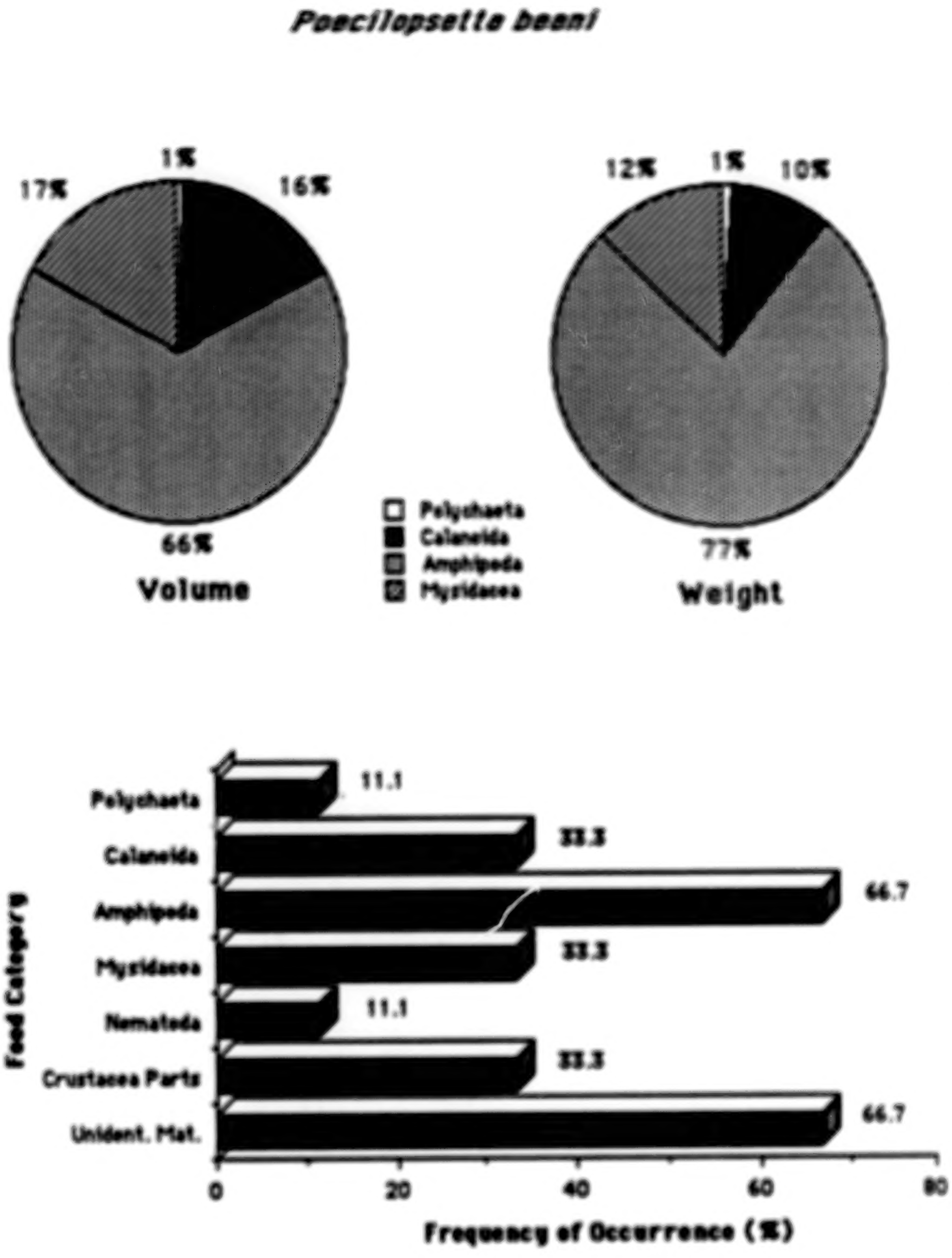
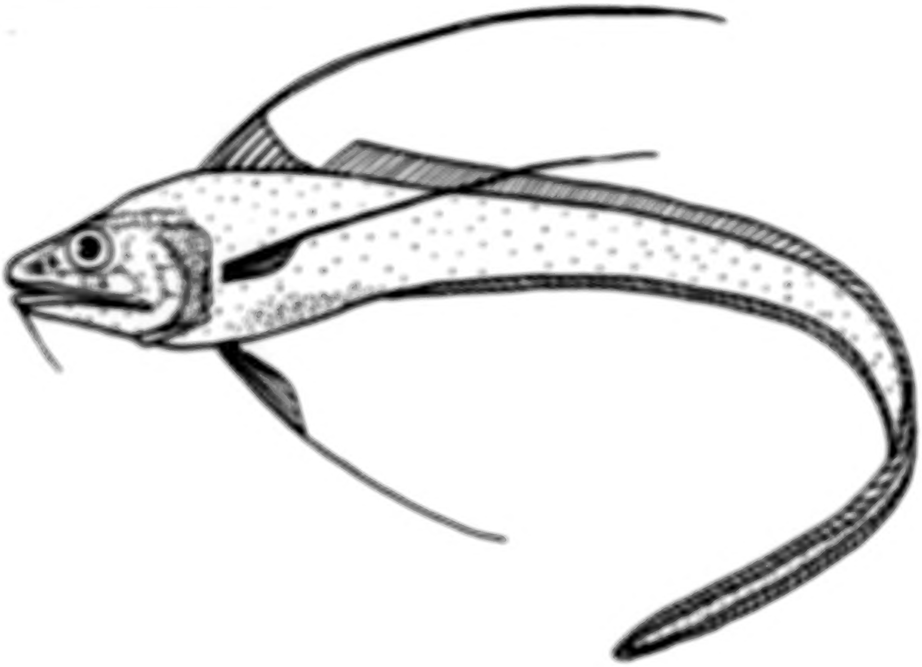


Figure 4-128. Stomach contents found in Poecilosetta beani plotted by volume and weight (upper) and by percent frequency of occurrence.

4.3.5.6 *Gadomus longifilis*



Gadomus longifilis occurs over a wide bathymetric range (630-2165 m) in tropical and sub-tropical regions of the Atlantic. In the east it is found from Portugal to the Gulf of Guinea and off the Azores and Canary Islands. In the western Atlantic, it has been reported from the east coast of Florida, throughout the Gulf of Mexico and the Caribbean Sea (Iwamoto 1970, Marshal and Iwamoto 1973).

G. longifilis were collected during all five cruises at depths ranging from 812-1203 m. The 191 specimens were taken in 11 trawls at 11 stations (Fig. 4-129), of which 110 (58%) were collected at Station WC11 (1135 m) and 31 (16%) at Station E4 (1170 m). Thus, nearly three-fourths of all specimens were taken within a narrow depth range of 1135-1170 m.

Specimens ranged in head length from 16-46 mm (mean = 32.3, S.E. = 0.5) (Fig. 4-130A). The largest sample of fish measured came from Cruise V (n = 85) and the length-frequency distribution was bimodal at 28 and 35 mm (Fig. 4-131). Specimens collected during Cruise II (n = 27) were unimodal at 22 mm. This differnce is apparently not depth related since most of the specimens were taken in the aforementioned 1135 and 1170 m trawls. Whether the difference is a yearly or geographic phenomenon or just an artifact of sample size is unknown.

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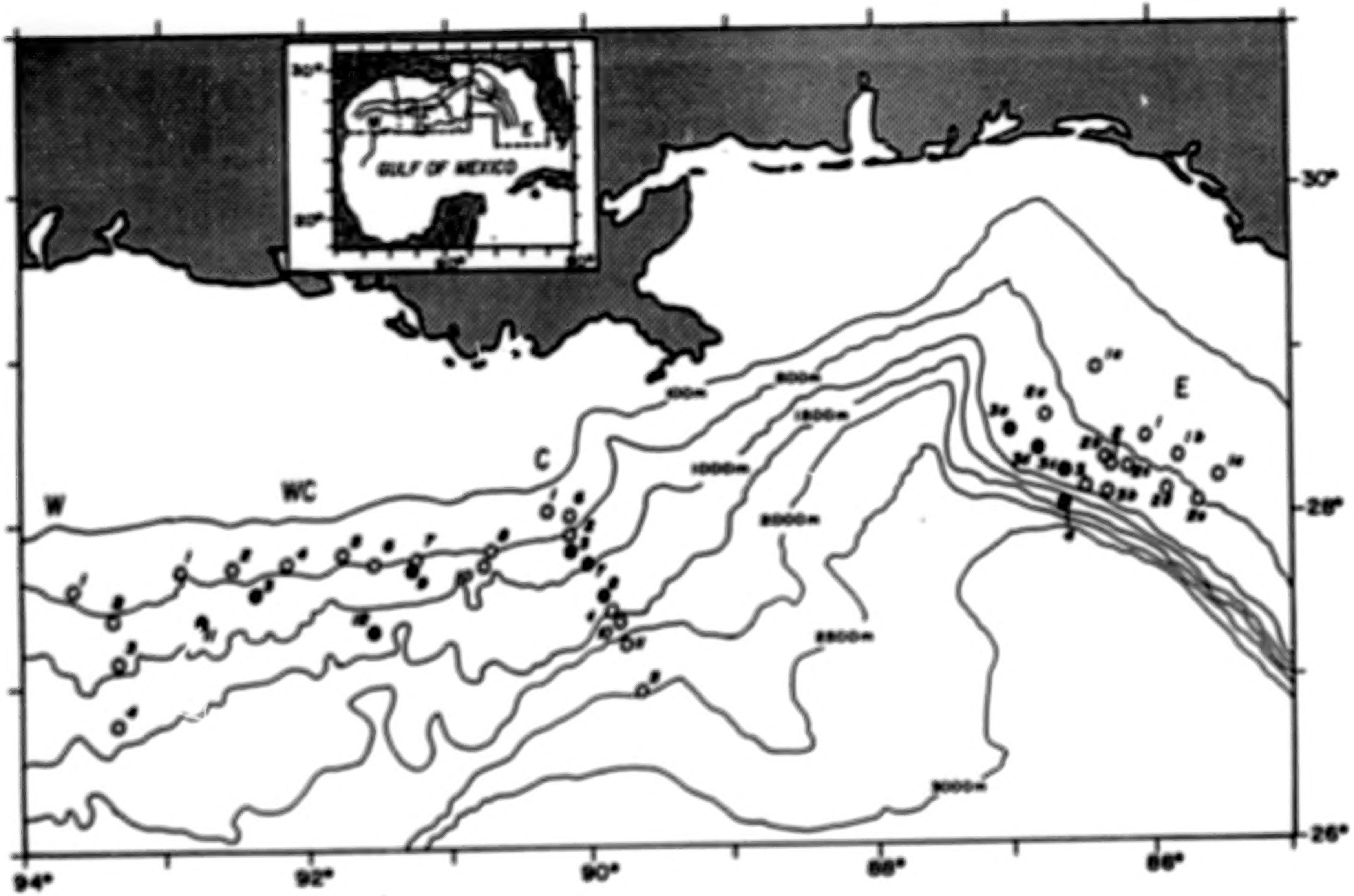


Figure 4-129. Locations where Gadomus longifilis were collected (closed circles).

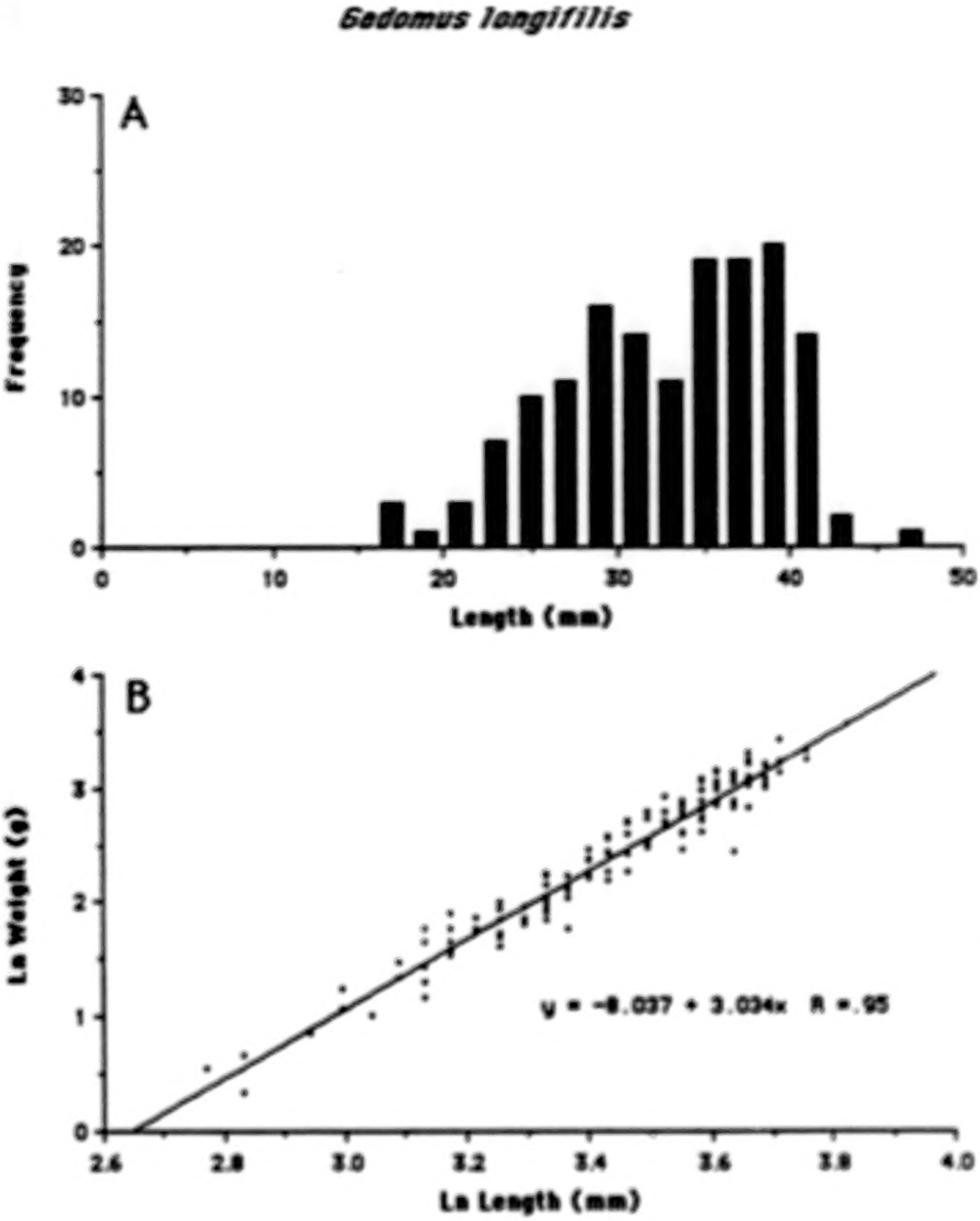


Figure 4-130. Frequency histogram (A) and size-weight relationship (B) for total lengths of Gadomus longifilis (all stations pooled).

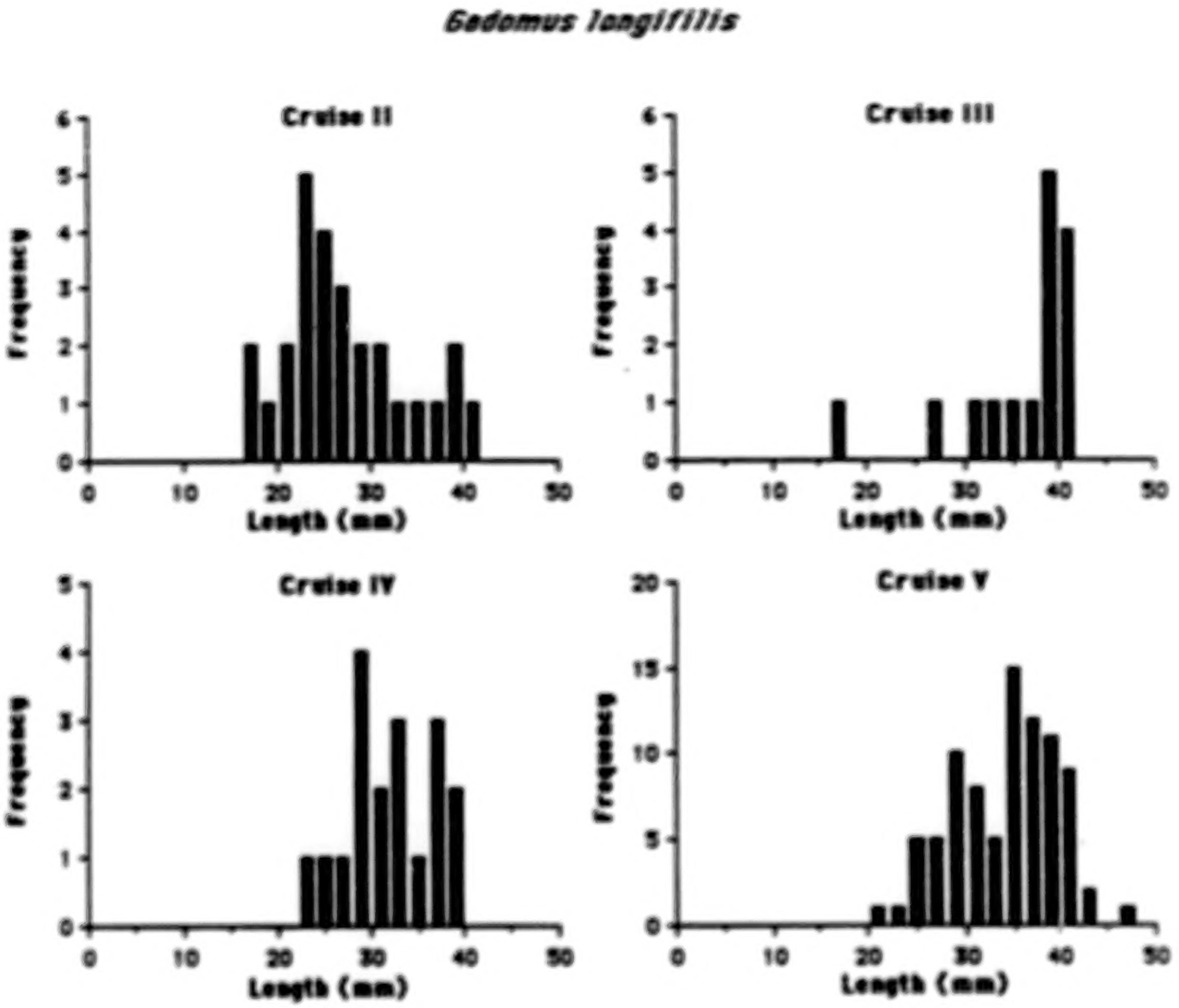


Figure 4-131. Frequency histograms for total lengths of Gadomus longifilis from individual cruises.

A regression of log transformed length-weight data showed a linear correlation ($y = -8.037 + 3.034x$, $r = 0.95$), indicating a uniform increase in condition across all specimens examined (Fig. 4-130).

Examination of 23 *G. longifilis* stomachs taken from three central and one eastern station indicated that this species feeds primarily on crustaceans. Calanoid copepods were the dominant food category consumed by frequency of occurrence and by volume (Fig. 4-132). Nantantia dominated in terms of weight. Amphipods and mysids also constituted substantial portions of the diet.

In relating diets to fin structure and jaw placement, Marshall (1965, 1977; p. 276) pointed out that members of the subfamily Bathygadinae (e.g., *Gadomus* spp.) are best suited for the consumption of mobile benthopelagic prey items. Our results generally tend to support Marshall's conclusions although small proportions of tanaidaceans and harpacticoid copepods do represent organisms that are typically benthic in nature.

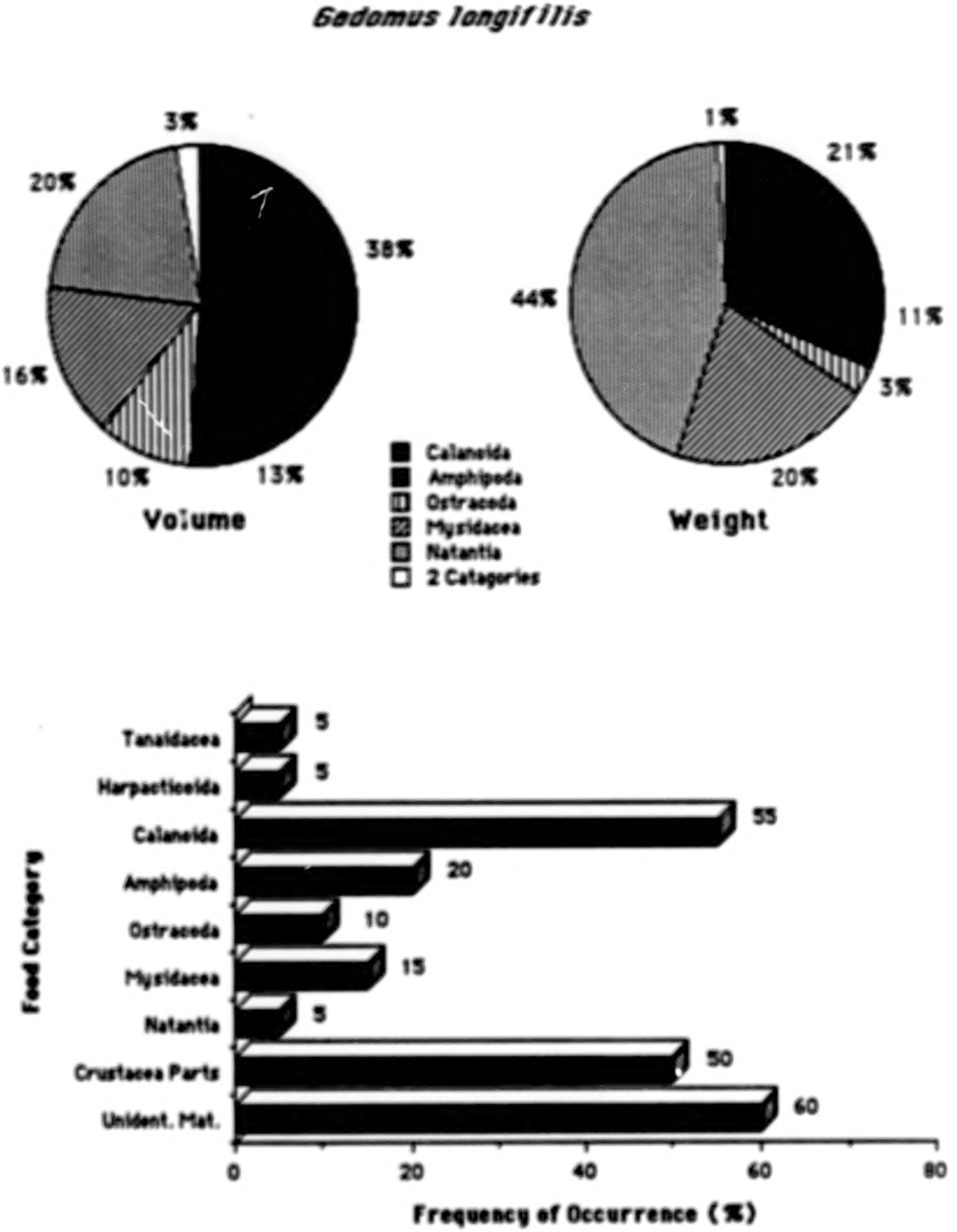
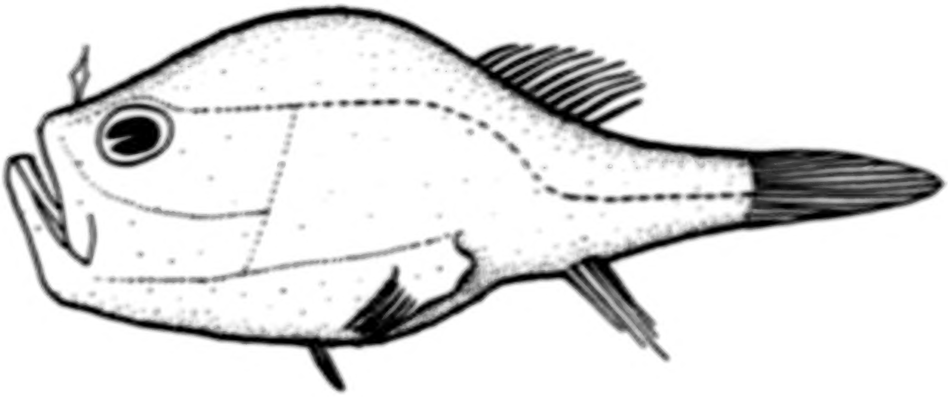


Figure 4-132. Stomach contents found in Gadomus longifilis plotted by volume and weight (upper) and by percent frequency of occurrence.

4.3.5.7 Chaunax pictus



A total of 150 C. pictus were collected during all five cruises and occurred in 21 trawls at 19 stations (Fig. 4-133). While C. pictus were taken at depths ranging from 423-786 m, nearly 82% (n = 123) of all specimens were collected between 603-663 m. This depth concentration appears to be geographically independent as specimens were present in all trawls made within this depth range, regardless of cruise or station.

Fish ranged in length from 30-170 mm with the size distribution being bimodal at 40 and 125-150 mm (Fig. 4-134A). The length-frequency distributions of specimens taken during Cruises IV and V suggest that depth distribution may be size related (Fig. 4-135). These two cruises accounted for 89% of all specimens examined. During Cruise IV, all but one of the 89 fish taken were collected between 615-629 m. The 21 specimens examined from Cruise V ranged in length from 50-220 mm and the size distribution was less distinct (Fig. 4-135). In terms of average depth of trawl nearly all C. pictus <100 mm were taken within the 603-663 m depth range.

The linear regression of ln transformed length/weight data showed a strong correlation ($y = -9.681 + 2.842x$, $r = 0.97$) and again suggests a uniform increase in condition across the length spectrum analyzed (Fig. 4-134B).

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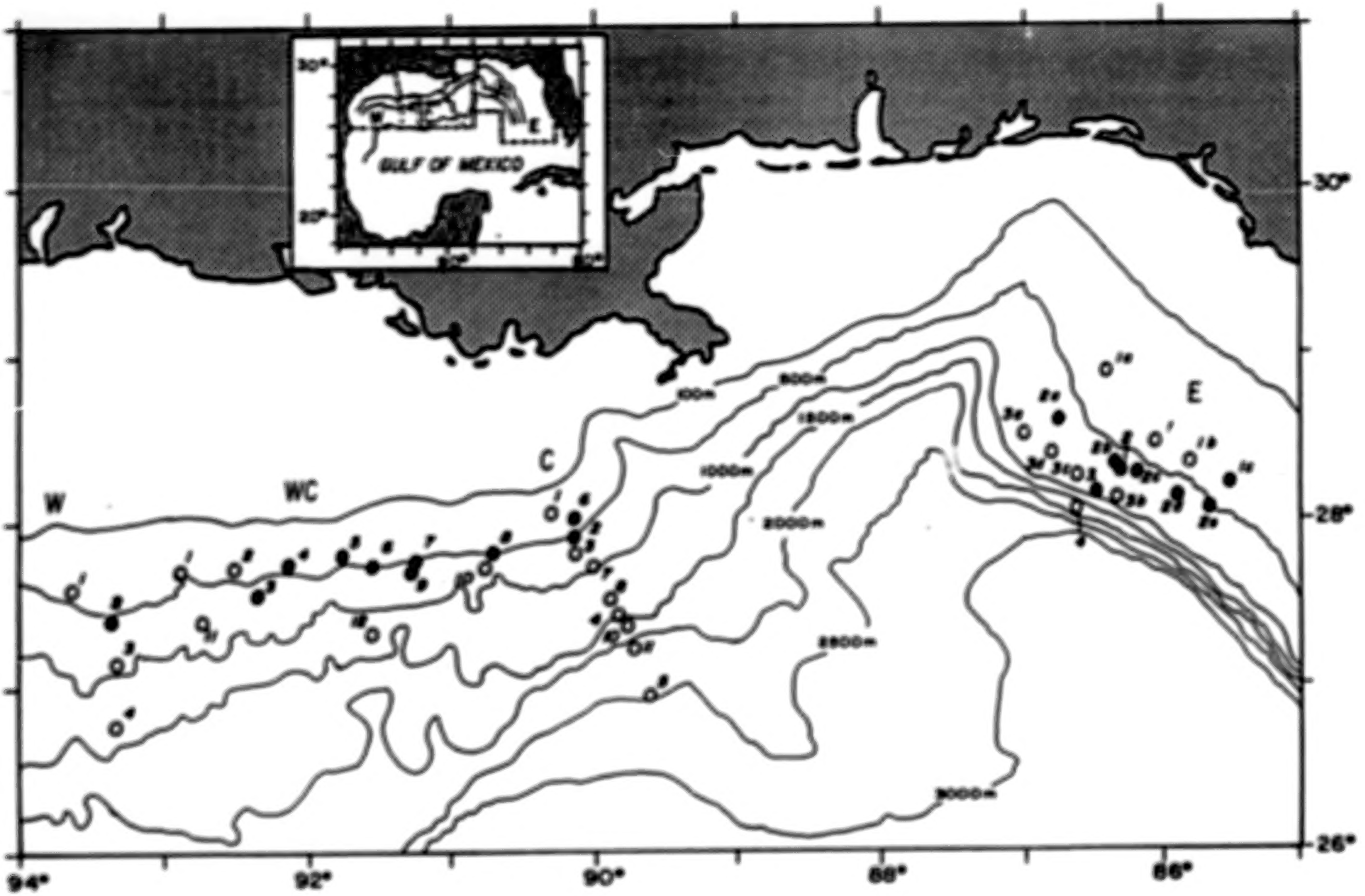

Figure 4-133. Locations where Chaunax pictus were collected (closed circles).

Chaunax pictus

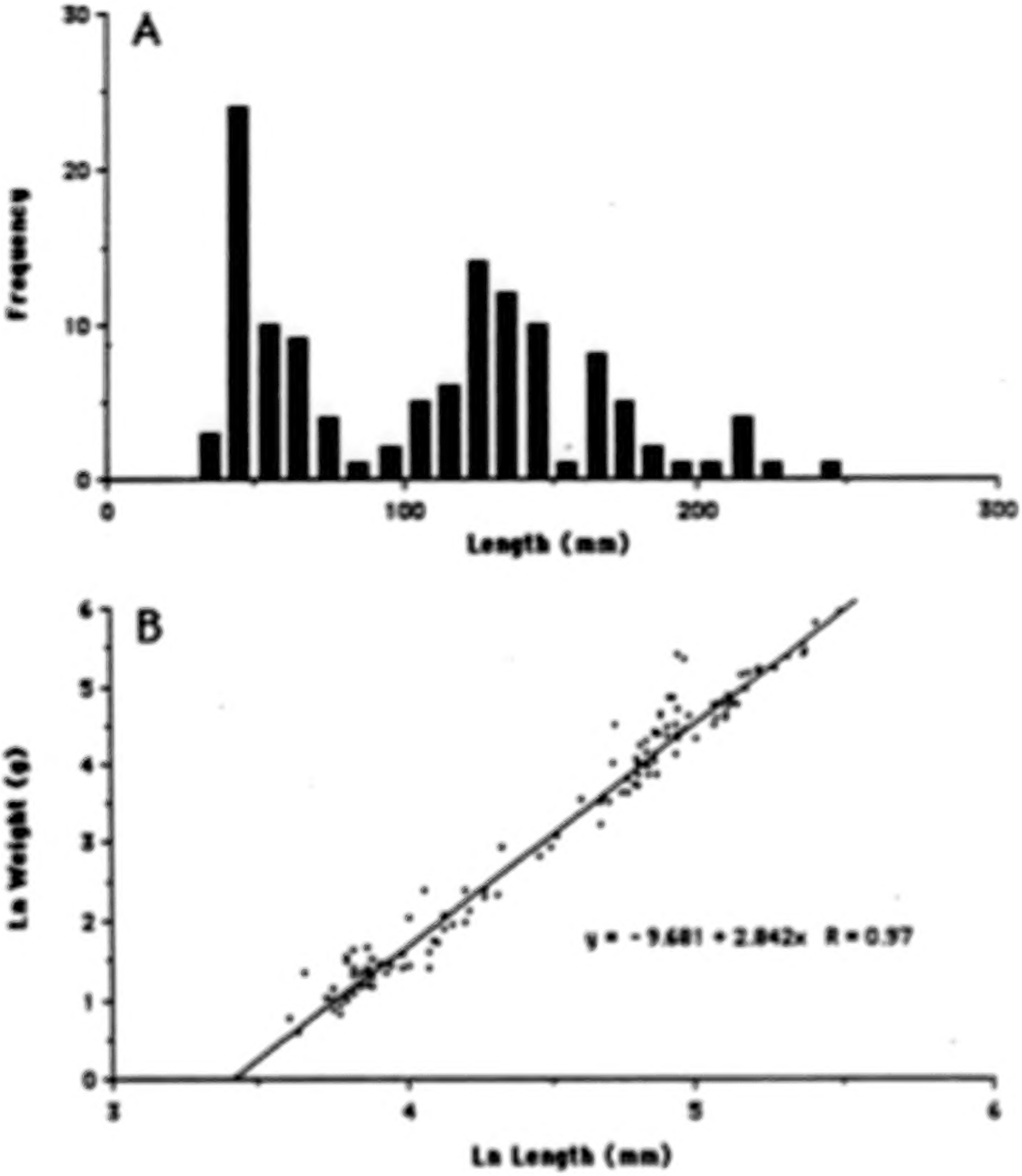

Figure 4-134. Frequency histogram (A) and size-weight relationship (B) for total lengths of *Chaunax pictus* (all stations pooled).

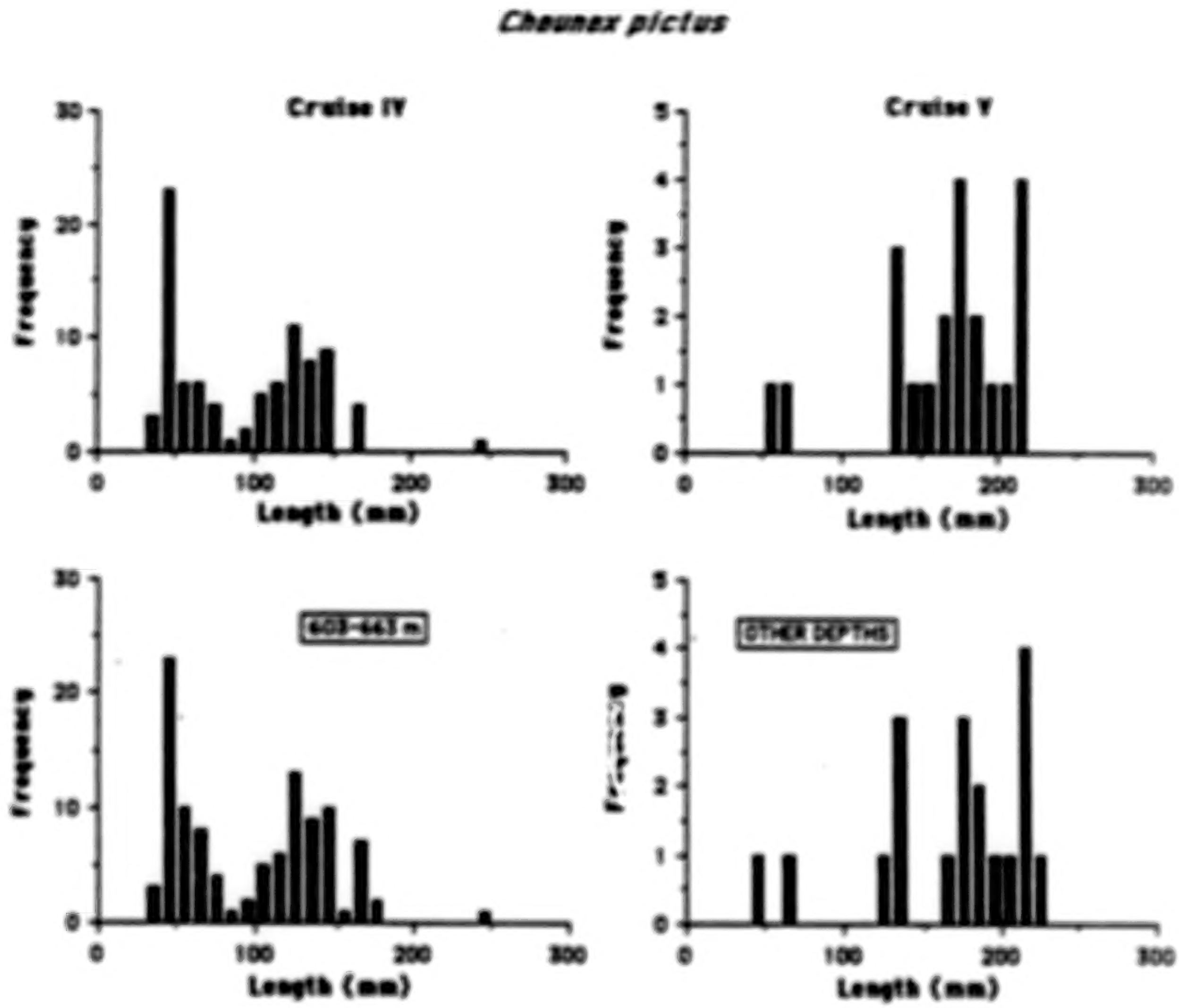

Figure 4-135. Frequency histograms for total lengths of Chaunax pictus from individual cruises.

4.3-5.8 *Coelorinchus coelorhynchus*

Coelorinchus coelorhynchus were collected during all five cruises and occurred in 17 trawls at 16 stations (Fig. 4-136). Of the 205 specimens collected, nearly 93% ($n = 190$) occurred at depths below 479 m. The remaining 15 individuals were taken at depths ranging from 521-663 m. Of the 15 trawls taken at depths below 557 m, 13 contained specimens of *C. coelorhynchus*. These results appeared independent of geographic location and season.

The 192 specimens of *C. coelorhynchus* were examined and they ranged in head length from 15-75 mm (mean = 48.9, S.E. = 0.9) (Fig. 4-137A). The overall length-frequency distribution was unimodal at 45-55 mm. The smallest fish were taken at Station C1 during Cruises I and II (Fig. 4-138); however, sample sizes were extremely small in both instances and prevent speculation as to size related differences in distribution.

As in most other cases, the ln length/ln weight regression for *C. coelorhynchus* was highly linear ($y = -4.220 + 3.249x$, $r = 0.99$) indicating a uniform exponential increase in condition across the length spectrum of fish examined (Fig. 4-137B).

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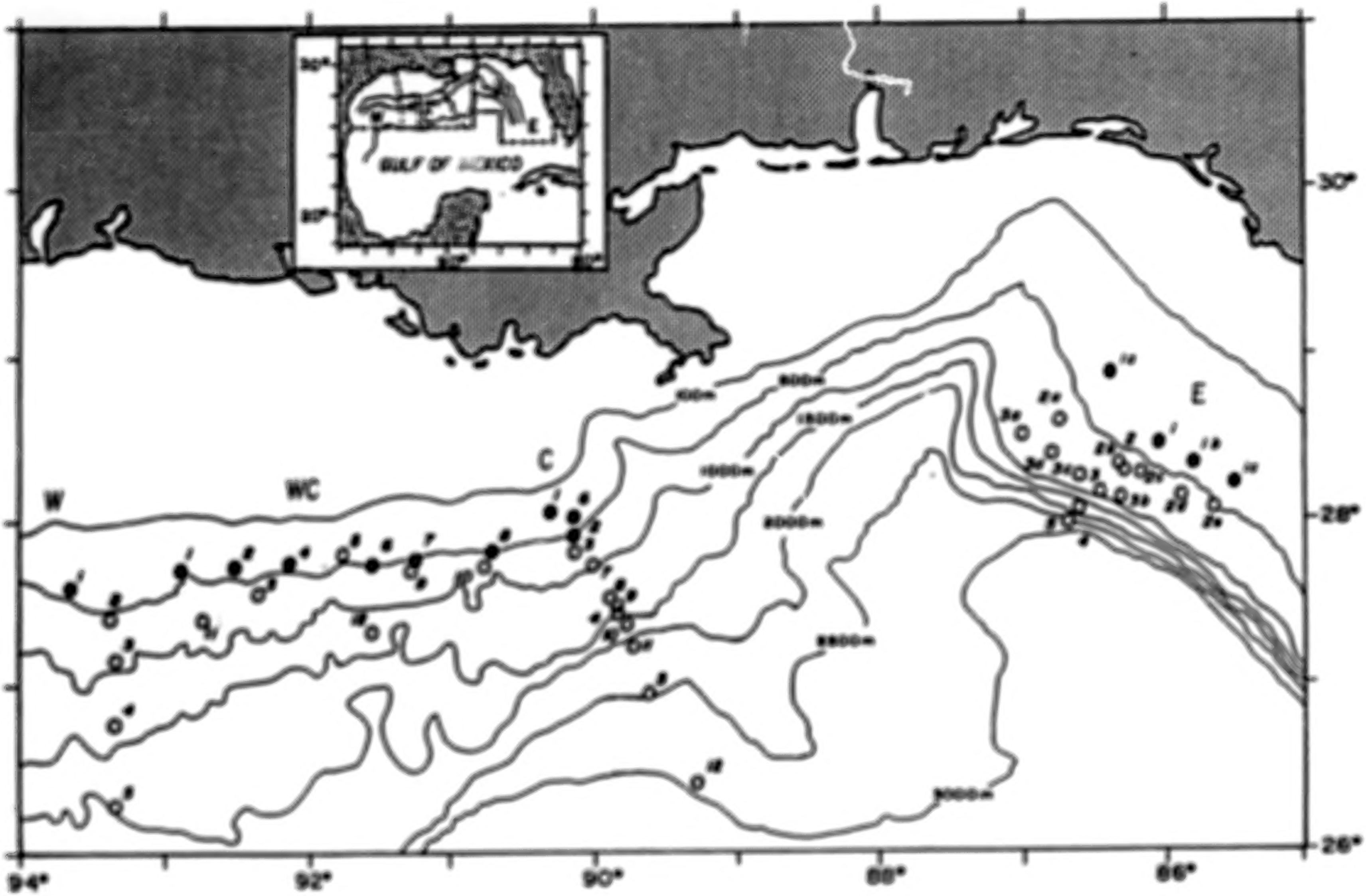


Figure 4-136. Locations where Coelorinchus coelorhynchus were collected (closed circles).

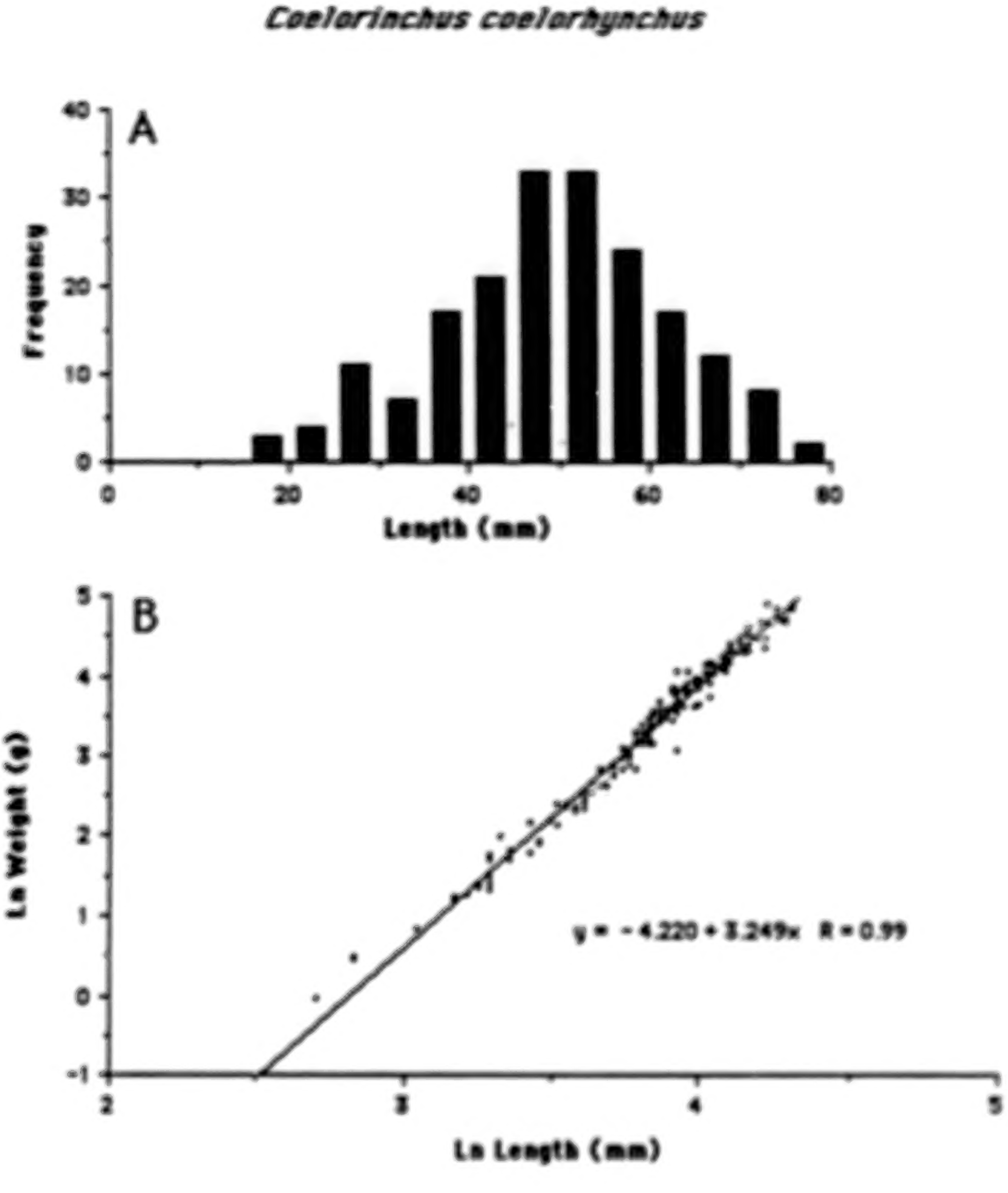


Figure 4-137. Frequency histogram (A) and size-weight relationship (B) for total lengths of Coelorinchus coelorhynchus (all stations pooled).

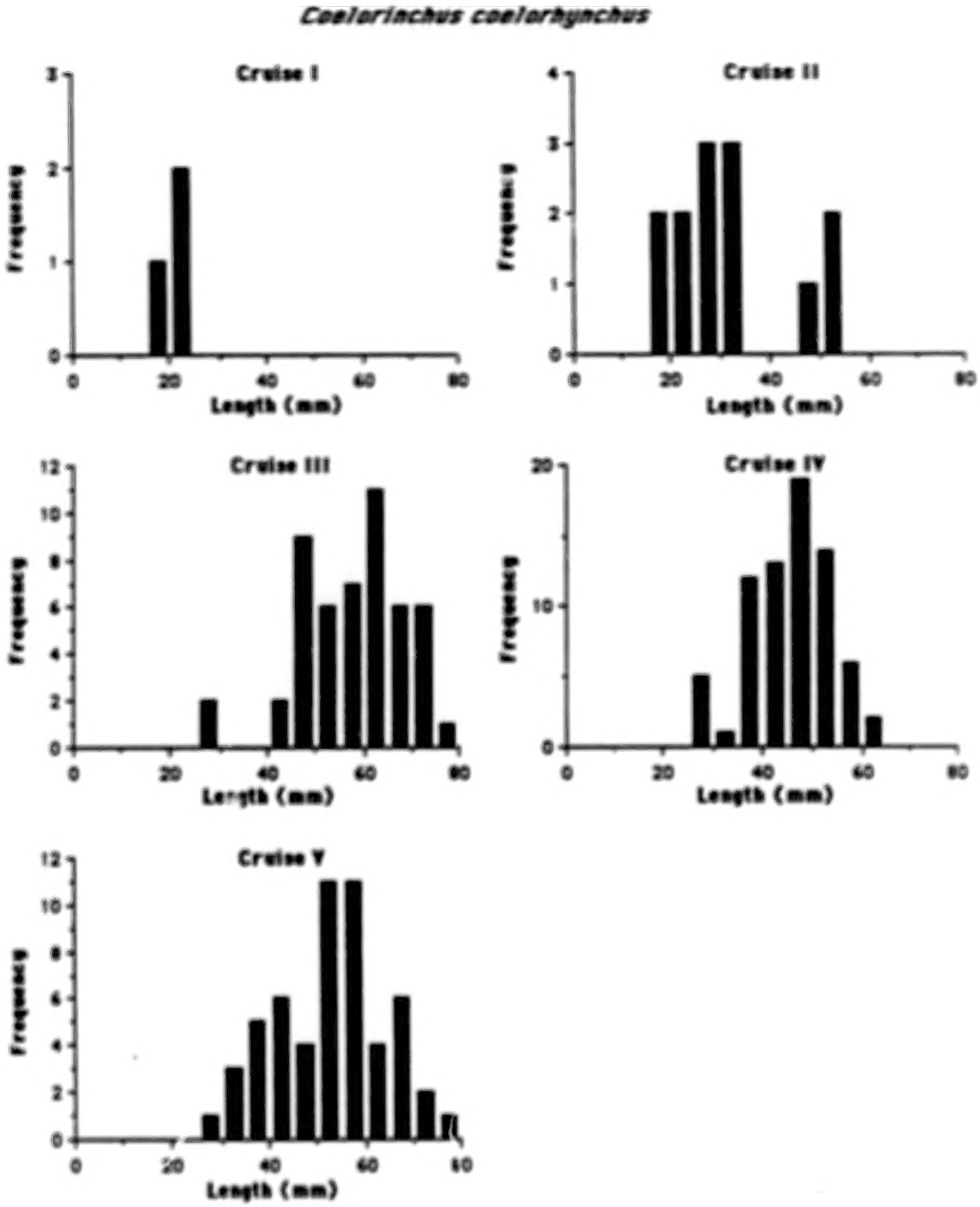
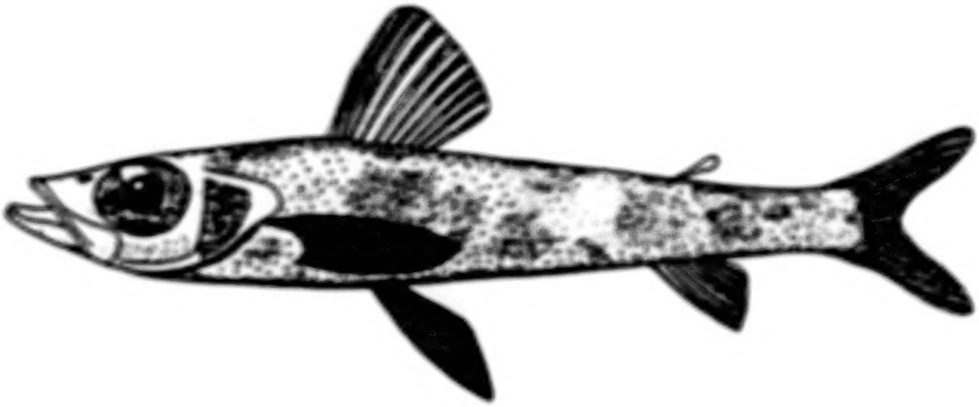


Figure 4-138. Frequency histograms for total lengths of Coelorinchus coelorhynchus from individual cruises.

4.3.5.9 Chlorophthalmus agassizi



The 305 specimens of C. *agassizi* were collected during all five cruises in 13 trawls at 11 stations. This species was consistently collected at depths ≤479 m, a trend that was evident regardless of station or trawl--C. *agassizi* were caught in all 13 trawls at or below 479 m (Fig. 4-139).

All 305 C. *agassizi* were examined and they ranged in length from 42-161 mm (mean = 95.0, S.E. = 1.2) (Fig. 4-140A). There were some differences in length-frequency distributions for the three most productive cruises (II, IV, V). The mode for Cruise IV was 20 mm lower than for Cruises II and V (Fig. 4-141). There was no indication that this difference was related either to depth or season and may be geographic in nature.

The regression of ln weight against ln length was again highly linear ($y = 12.919$, S.E. $= 3.319x$, $r = 0.98$) (Fig. 4-140B).

The stomach contents of 21 C. *agassizi* contained 13 identifiable prey items (Fig. 4-142). In terms of frequency of occurrence, Amphipoda, Calanoida and Nantantia were the most dominant organisms present. Calanoida (21%), Osteichthys (20%), Nantantia (18%), Amphipoda (15%) and Polychaeta (12%) were most abundant by volume while Osteichthys (47%), Calanoida (21%) and Nantantia (14%) dominated by weight.

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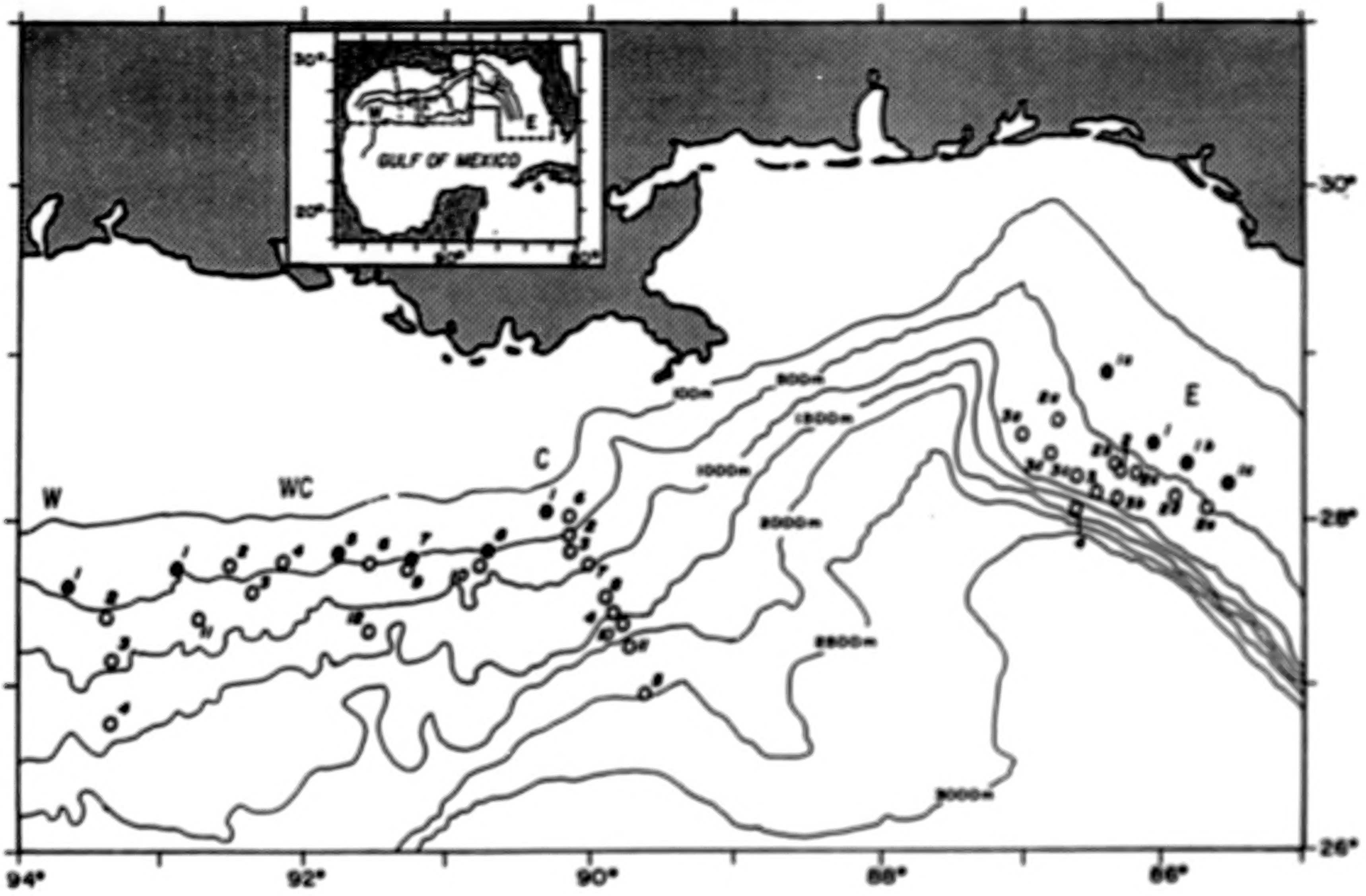


Figure 4-139. Locations where Chloropthalmus agassizi were collected (closed circles).

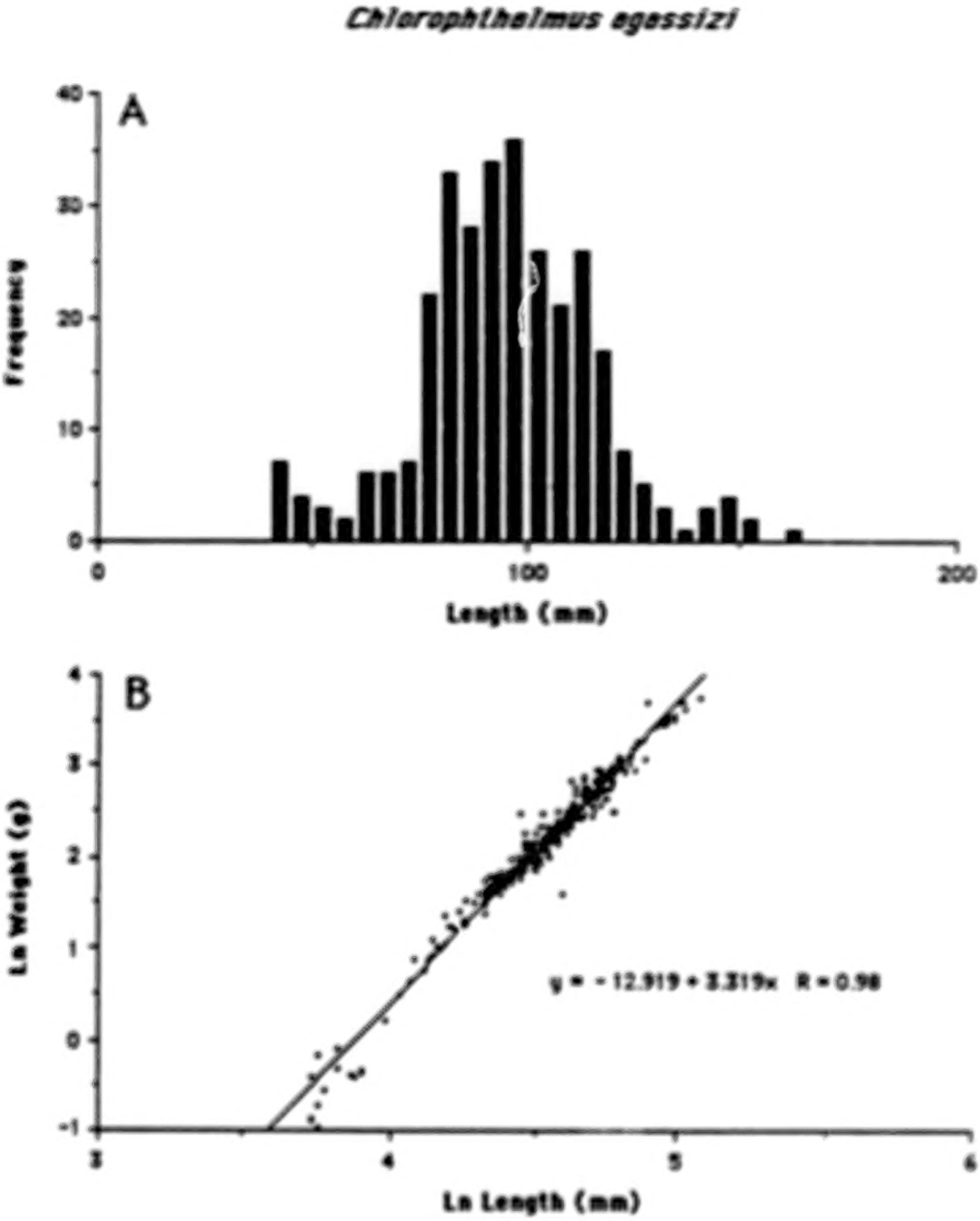


Figure 4-140. Frequency histogram (A) and size-weight relationship (B) for total lengths of Chloropthalmus agassizi (all stations pooled).

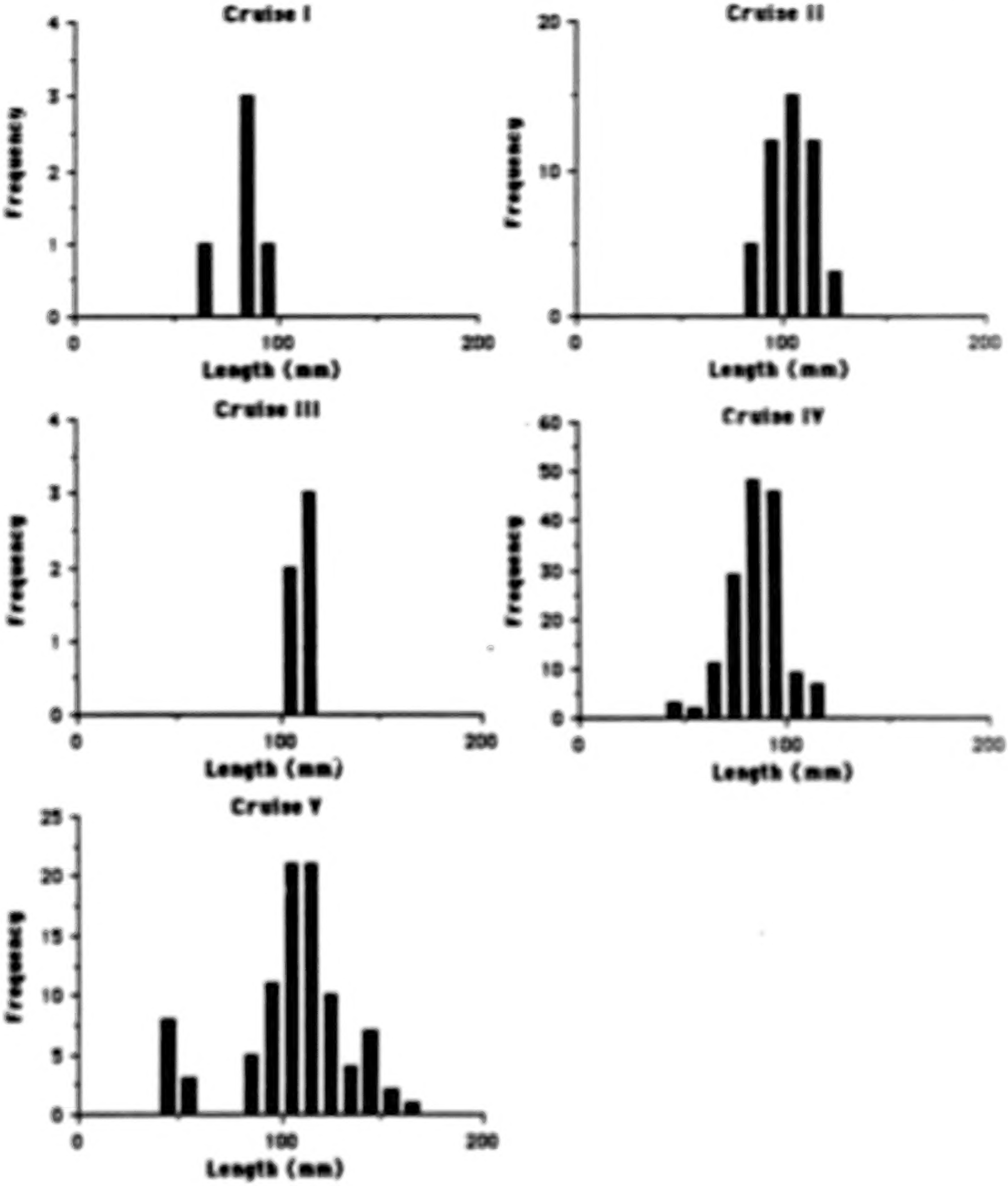


Figure 4-141. Frequency histograms for total lengths of *Chloropthalmus agassizi* from individual cruises.

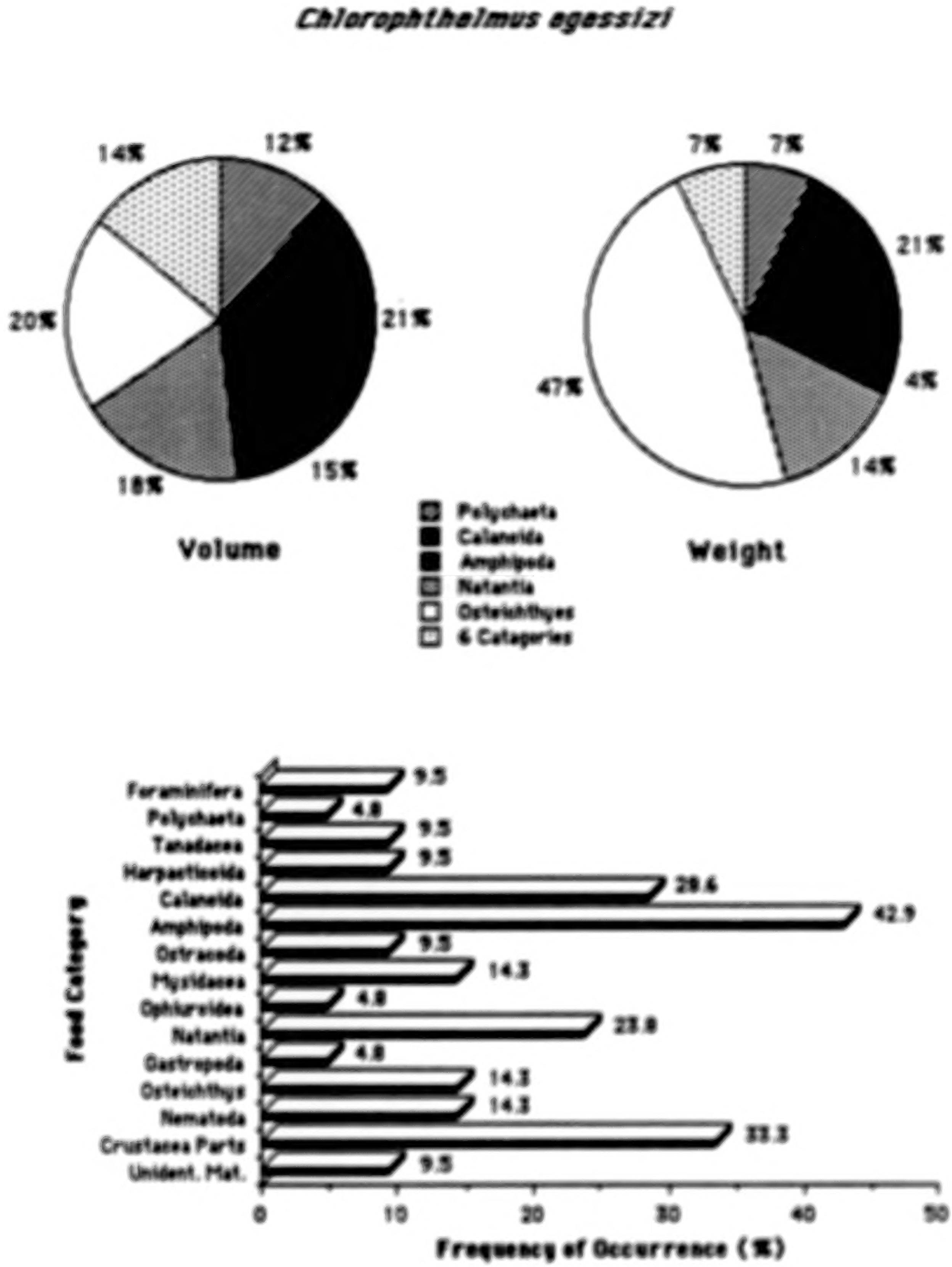
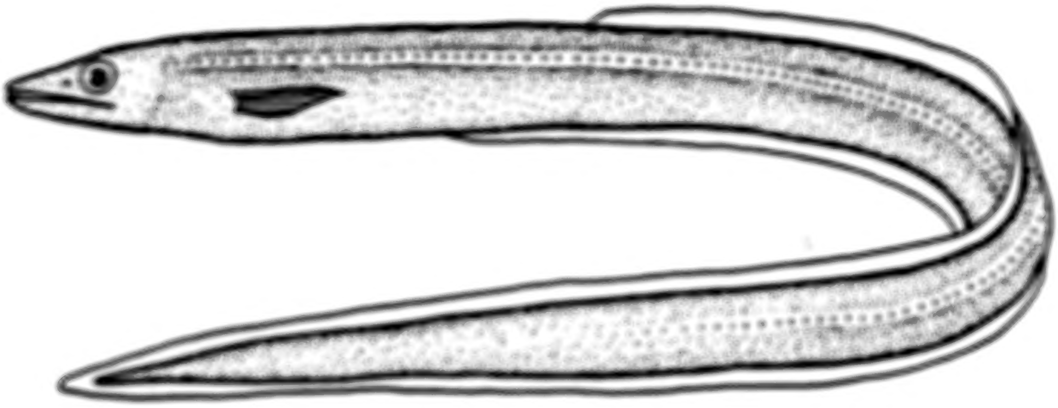


Figure 4-142. Stomach contents found in *Chloropthalmus agassizi* plotted by volume and weight (upper) and by percent frequency of occurrence.

4.3.5.10 *Synaphrobranchus oregoni*



Synaphrobranchus oregoni was the fourth most abundant fish species collected. A total of 354 specimens were taken during all five cruises in 27 trawls at 24 stations (Fig. 4-143). *S. oregoni* were taken at depths (average depth of trawl) ranging from 479-1203 m. This bathymetric distribution was not consistent across trawls and stations as seven (21%) of 34 trawls taken within this depth range failed to catch specimens.

While the 285 examined specimens of *S. oregoni* ranged in total length from 120-691 mm (mean = 415.2, S.E. = 5.4), better than 90% of all individuals exceeded 300 mm (Fig. 4-144A). The dominant size aggregation between 300-600 mm was evident during each of the four most productive cruises--II, III, IV, and V (Fig. 4-145). There was some evidence of size-dependent depth distribution in that the vast majority of fish <300 mm were taken at depths of approximately 750-850 m.

Length-weight regression analysis on ln transformed data yielded a highly linear relationship ($y = -17.570 + 3.630$, $r = 0.96$) across all size groups tested. Results included four noticeble outliers (Fig. 4-144B).

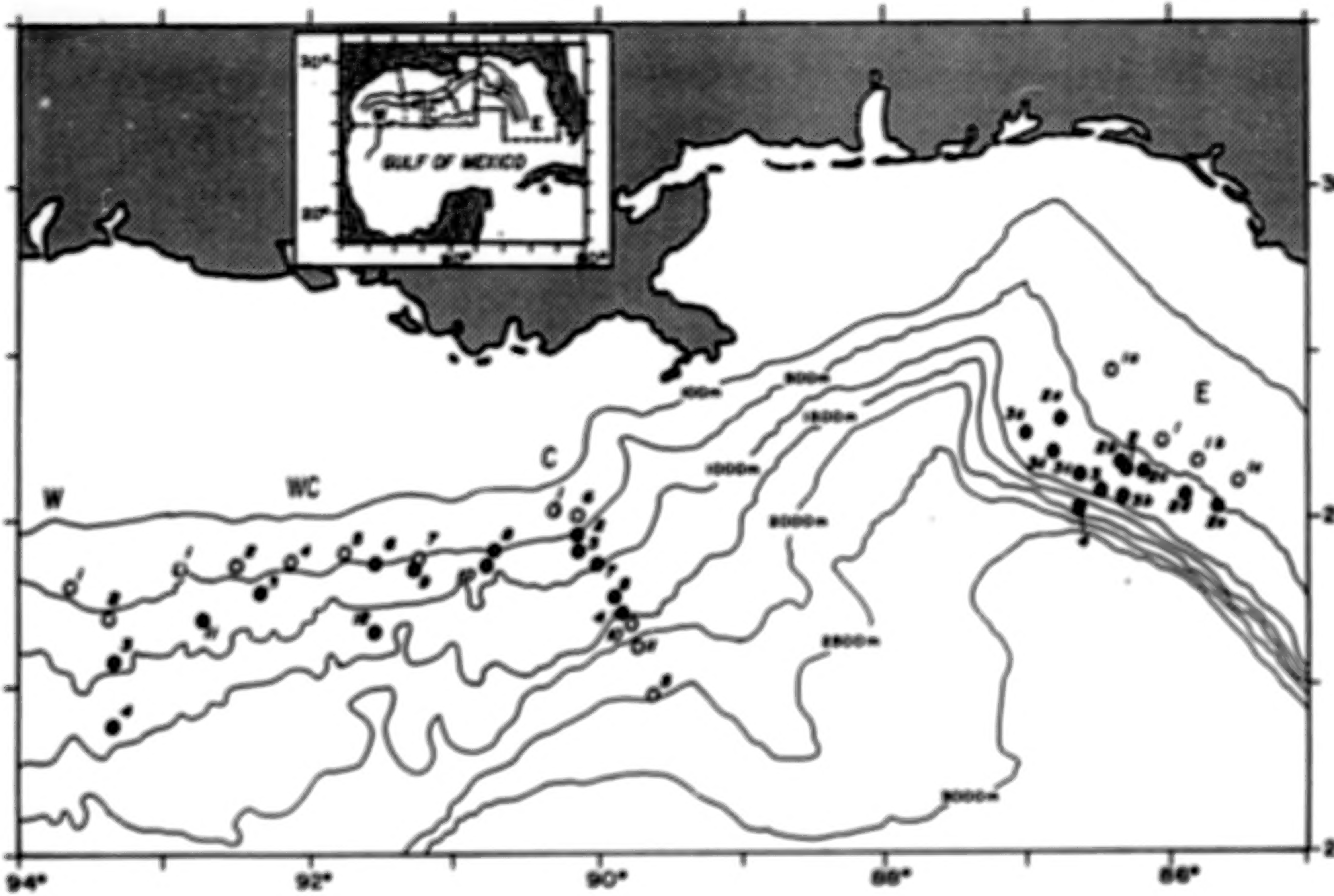


Figure 4-143. Locations where Synaphobranchus oregoni were collected (closed circles).

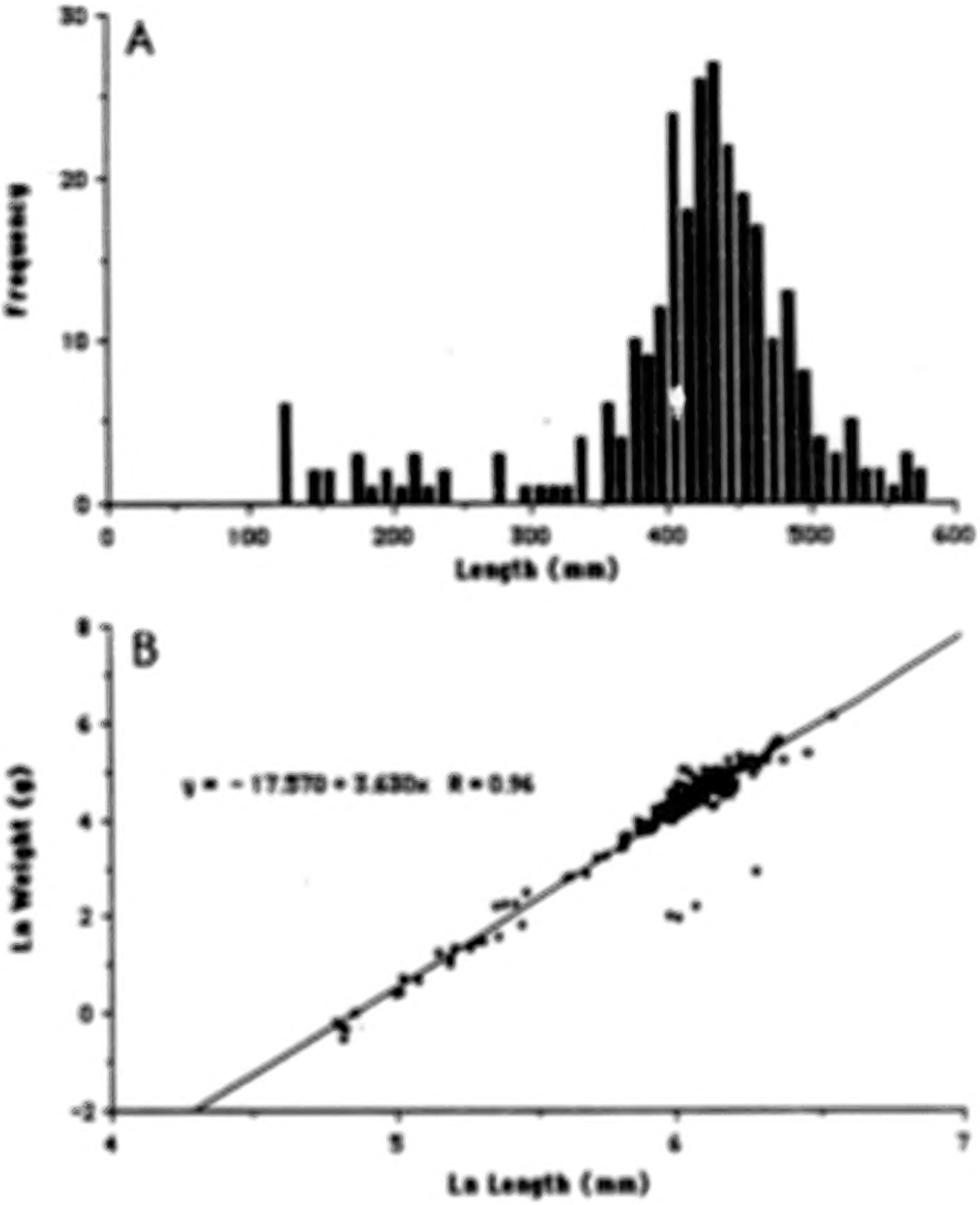


Figure 4-144. Frequency histogram (A) and size-weight relationship (B) for total lengths of Synaphrobranchus oregoni (all stations pooled).

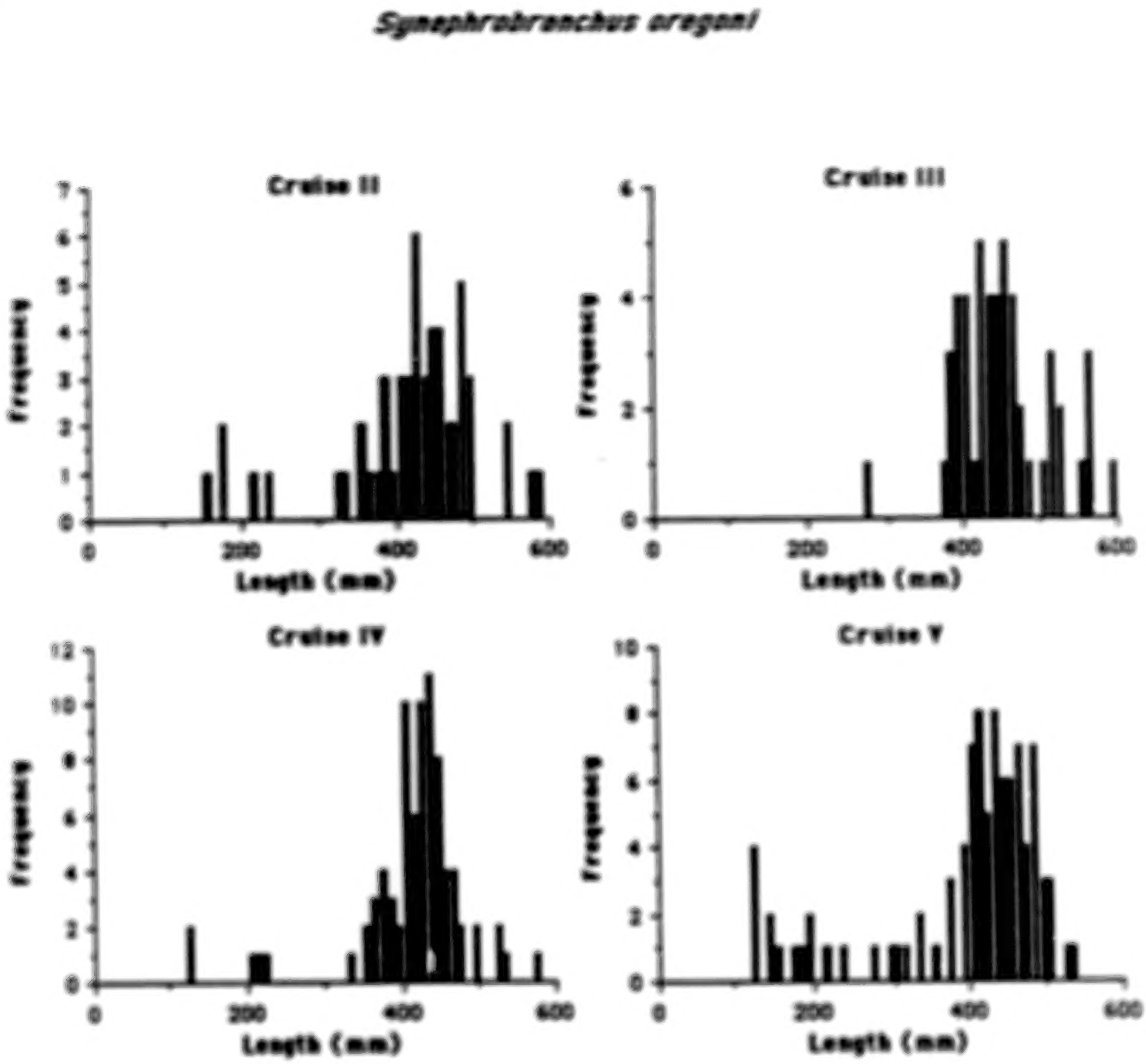


Figure 4-145. Frequency histograms for total lengths of Synaphobranchus oregoni from individual cruises.

The stomach contents of 24 specimens of S. oregoni were examined. Of the five identifiable food items, Osteichthys, Colecoidea and Nantantia constituted nearly 100% of stomach content by volume and weight--with Osteichthys being most dominant (Fig. 4-146). Osteichthys also was the most abundant prey item in terms of frequency of occurrence and was followed by Colecoidea.

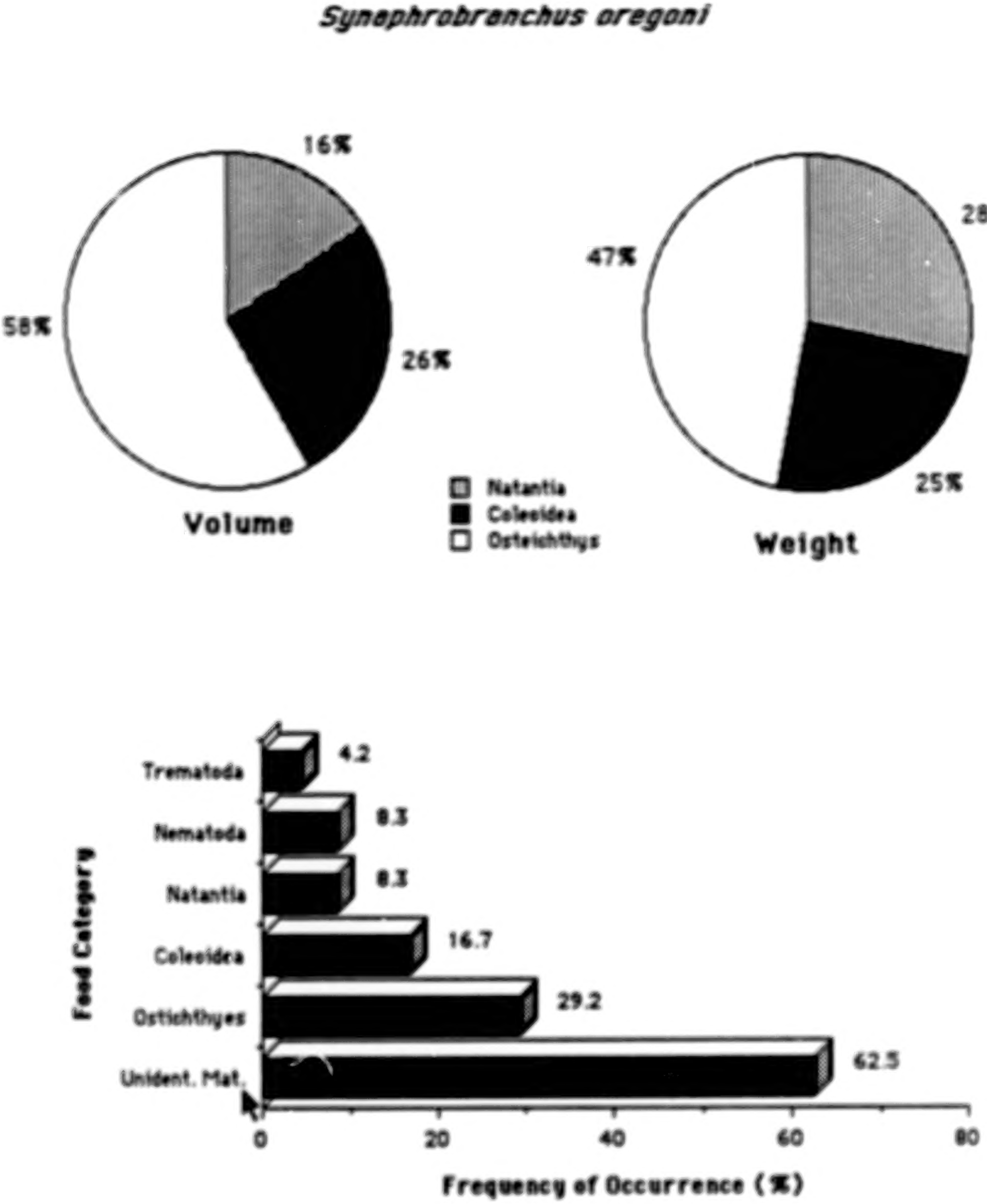
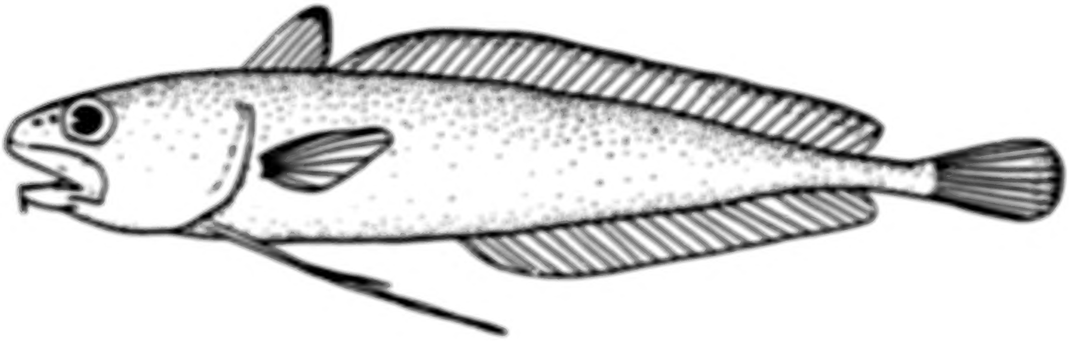


Figure 4-146. Stomach contents found in Synaphobranchus oregoni plotted by volume and weight (upper) and by percent frequency of occurrence.

4.3.5.11 Urophysis cirratus



Urophysis cirratus was the second most abundant fish species collected during this project. During all five cruises, a total of 380 specimens were collected in 19 trawls at 16 stations (Fig. 4-147). Based upon average depth of trawl, this species was collected at depths of 329-625 m. The greatest concentrations, however, occurred at depths ranging from 329-479 m and this trend was consistent among all trawls and stations--U. cirratus were present in all 14 trawls taken within the 329-479 m depth range and accounted for 92% of all specimens collected.

The 300 specimens of U. cirratus that were examined ranged in total length from 230-517 mm (mean = 328.4, S.E. = 3.1) (Fig. 4-148A). There were differences in length-frequency distributions among cruises (Fig. 4-149); however, much of this was attributable to size differentials at individual stations. Distribution in terms of specific size cohorts was difficult to characterize by depth, location and season because of the numerous differentials among stations.

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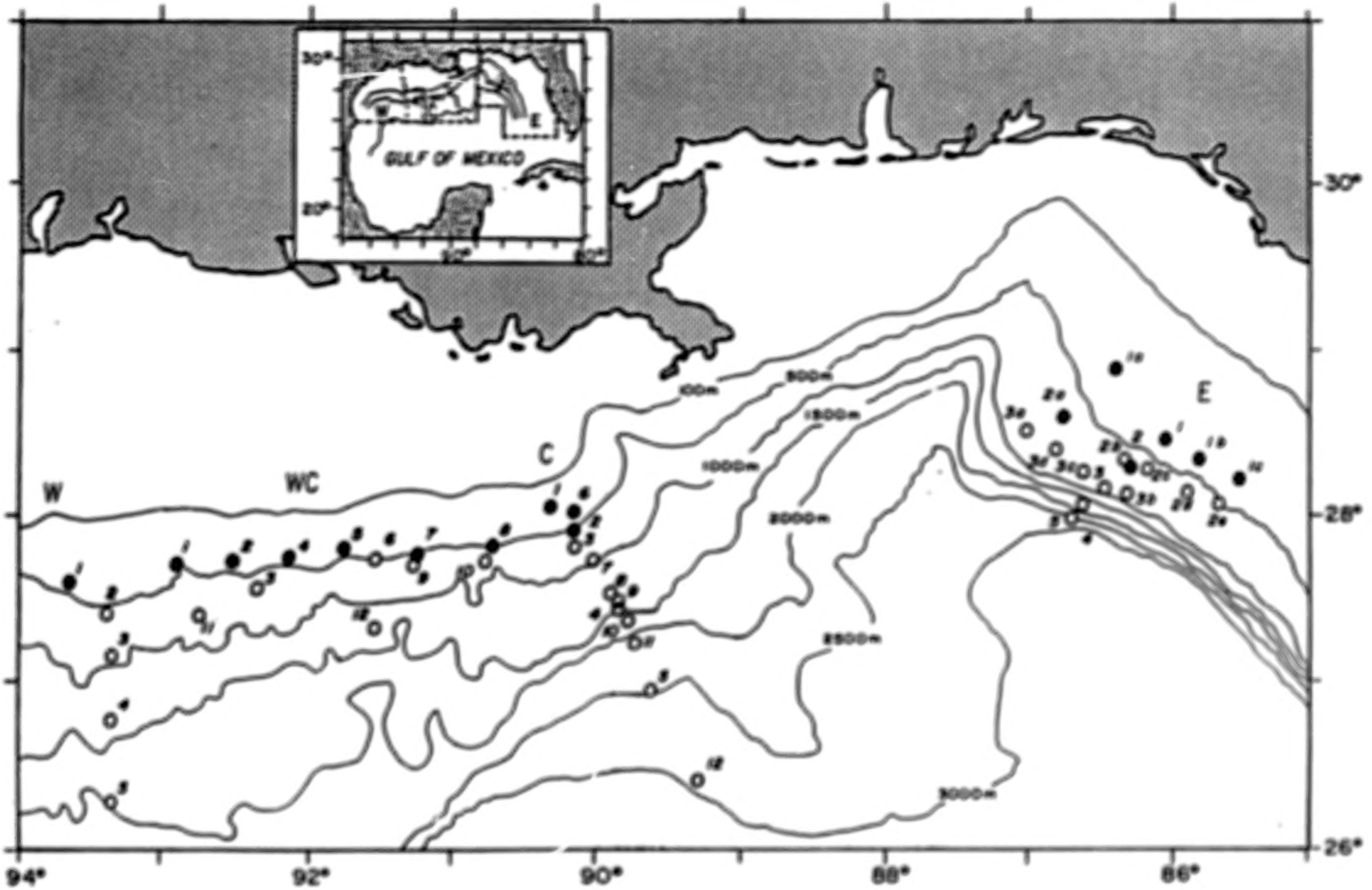


Figure 4-147. Locations where Urophysis cirratus were collected (closed circles).

Urophycis cirratus

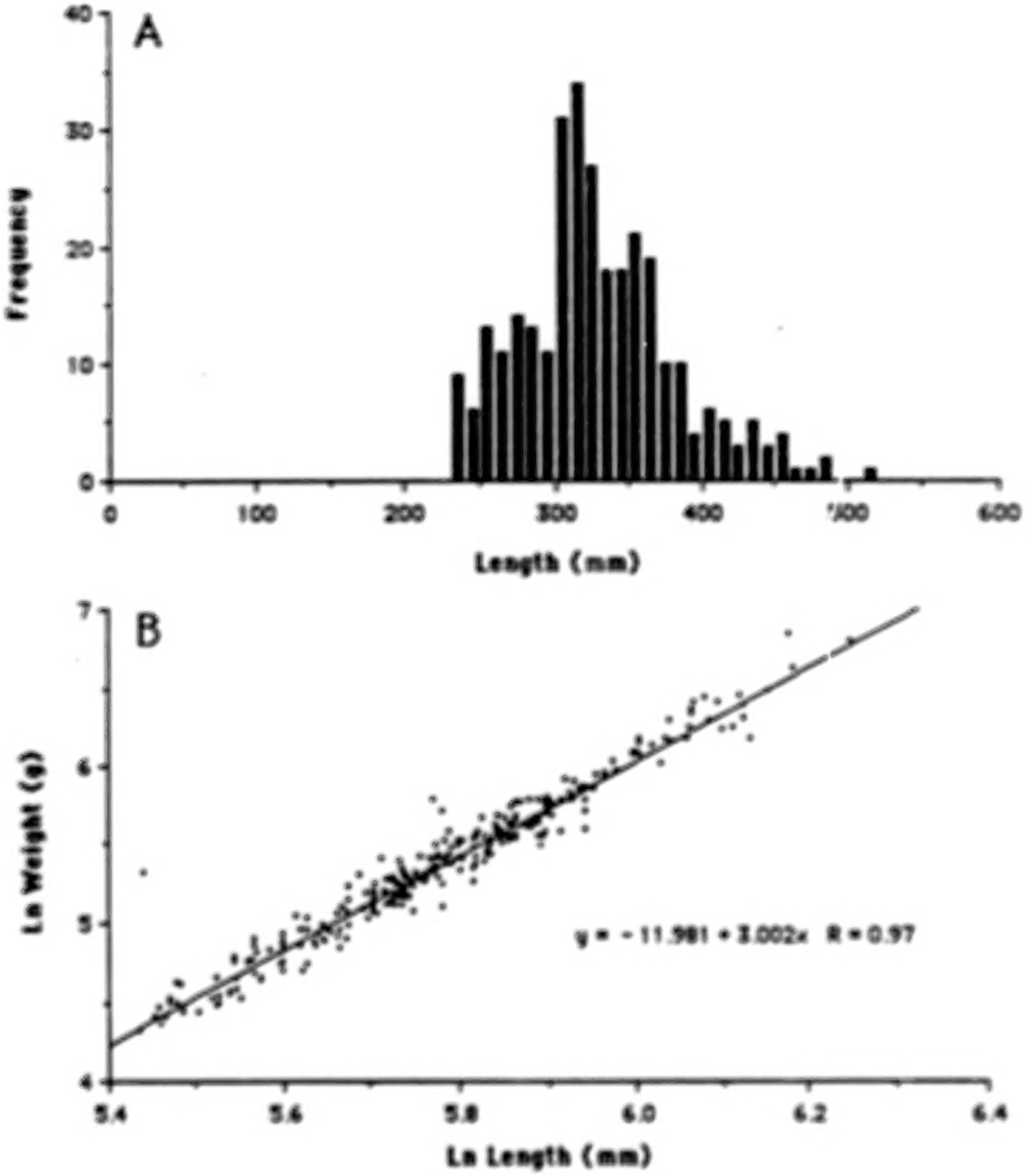


Figure 4-148. Frequency histogram (A) and size-weight relationship (B) for total lengths of Urophysis cirratus (all stations pooled).

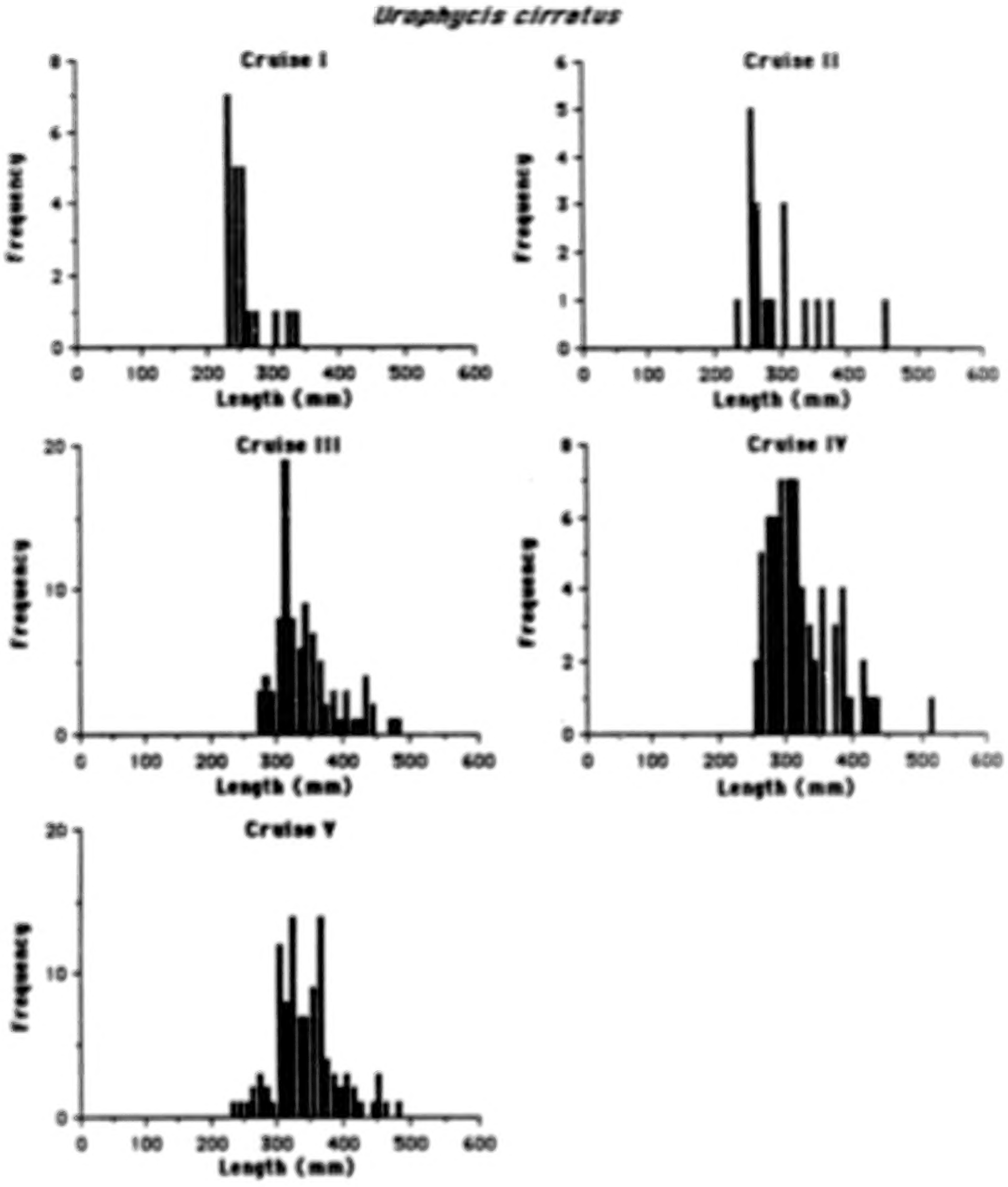
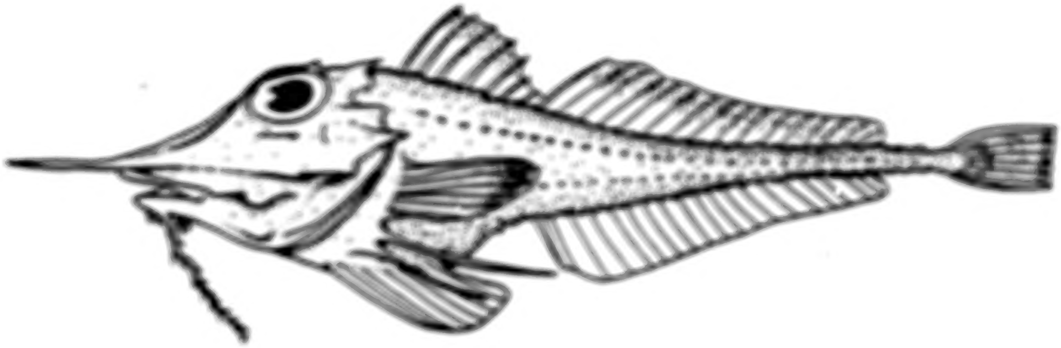


Figure 4-149. Frequency histograms for total lengths of Urophysis cirratus from individual cruises.

4.3.5.12 Peristedion grayae



Peristedion grayae were collected during all five cruises in 17 trawls at 17 stations (Fig. 4-150). Of the 128 individuals taken, 127 were caught at depths ranging from 329-663 m. A single specimen was caught at 1107 m.

The 122 specimens examined ranged in total length from 55-205 mm (mean = 121.0, S.E. = 4.3) (Fig. 4-151A). Length-frequency distributions indicated a greater preponderance of smaller individuals during Cruises II and IV (Fig. 4-152); however, these results reflect the difference in effort at depth among cruises. Specimens of *P. grayae* <125 mm were more abundant at depths of 329-368 m while fish >125 mm were more abundant at depths of 474-663 m.

The ln length/ln weight relationship for *P. grayae* was linear (y = -11.632 + 2.94x, r = 0.99) across the entire length spectrum and indicates a uniform exponential increase in condition for all size cohorts (Fig. 4-151B).

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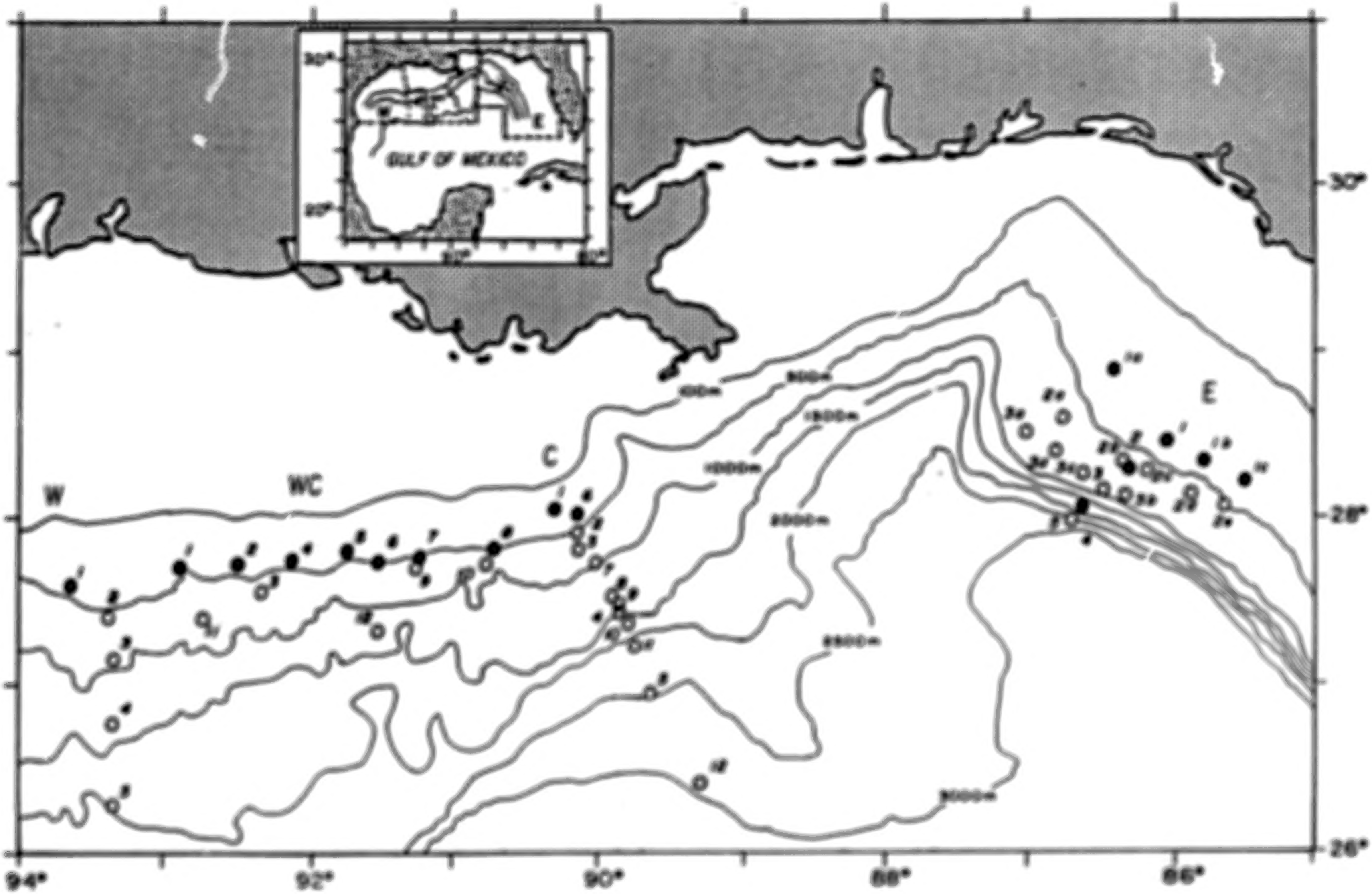

Figure 4-150. Locations where Peristedion grayae were collected (closed circles).

Peristedion grayae

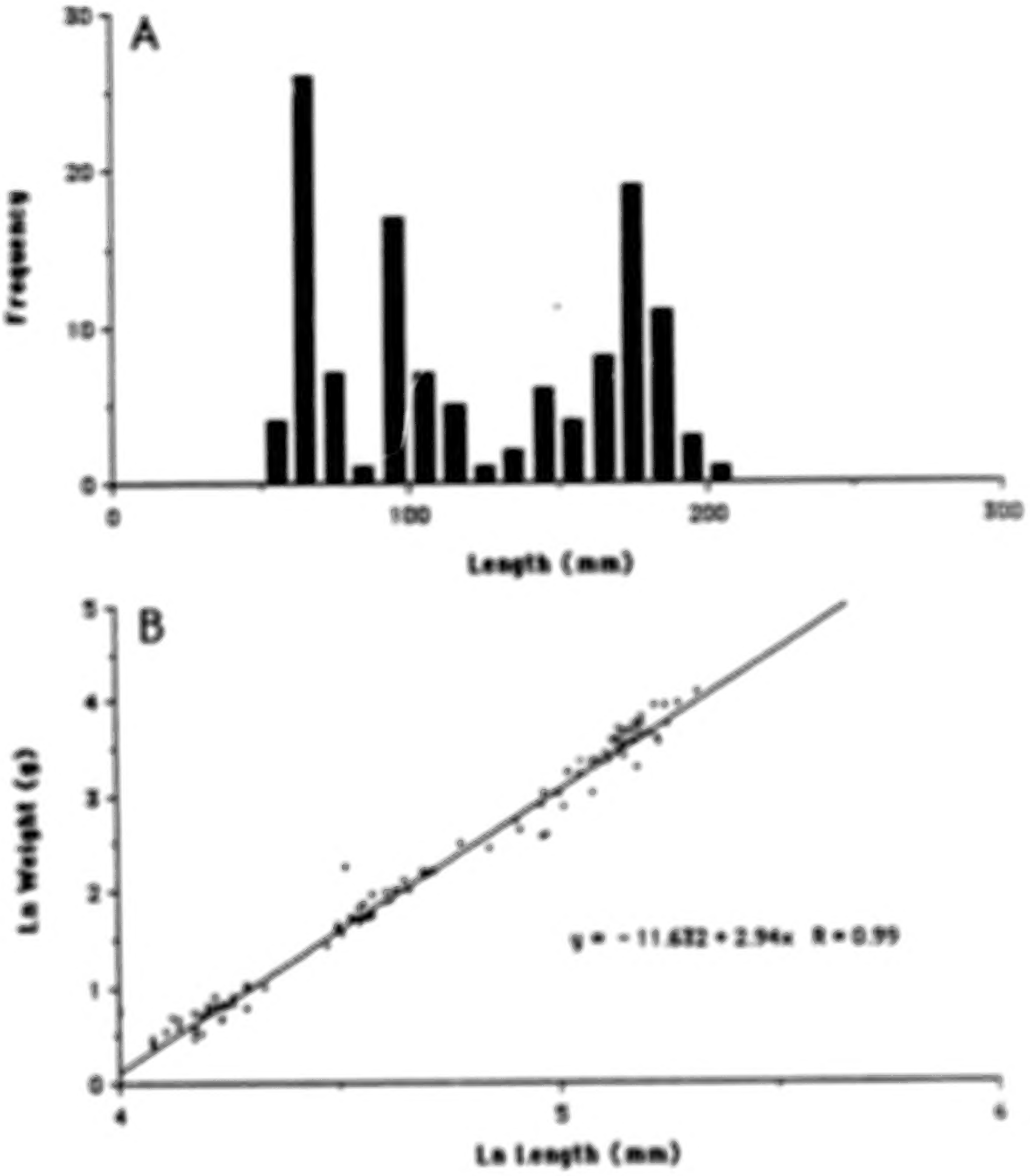

Figure 4-151. Frequency histogram (A) and size-weight relationship (B) for total lengths of *Peristedion grayae* (all stations pooled).

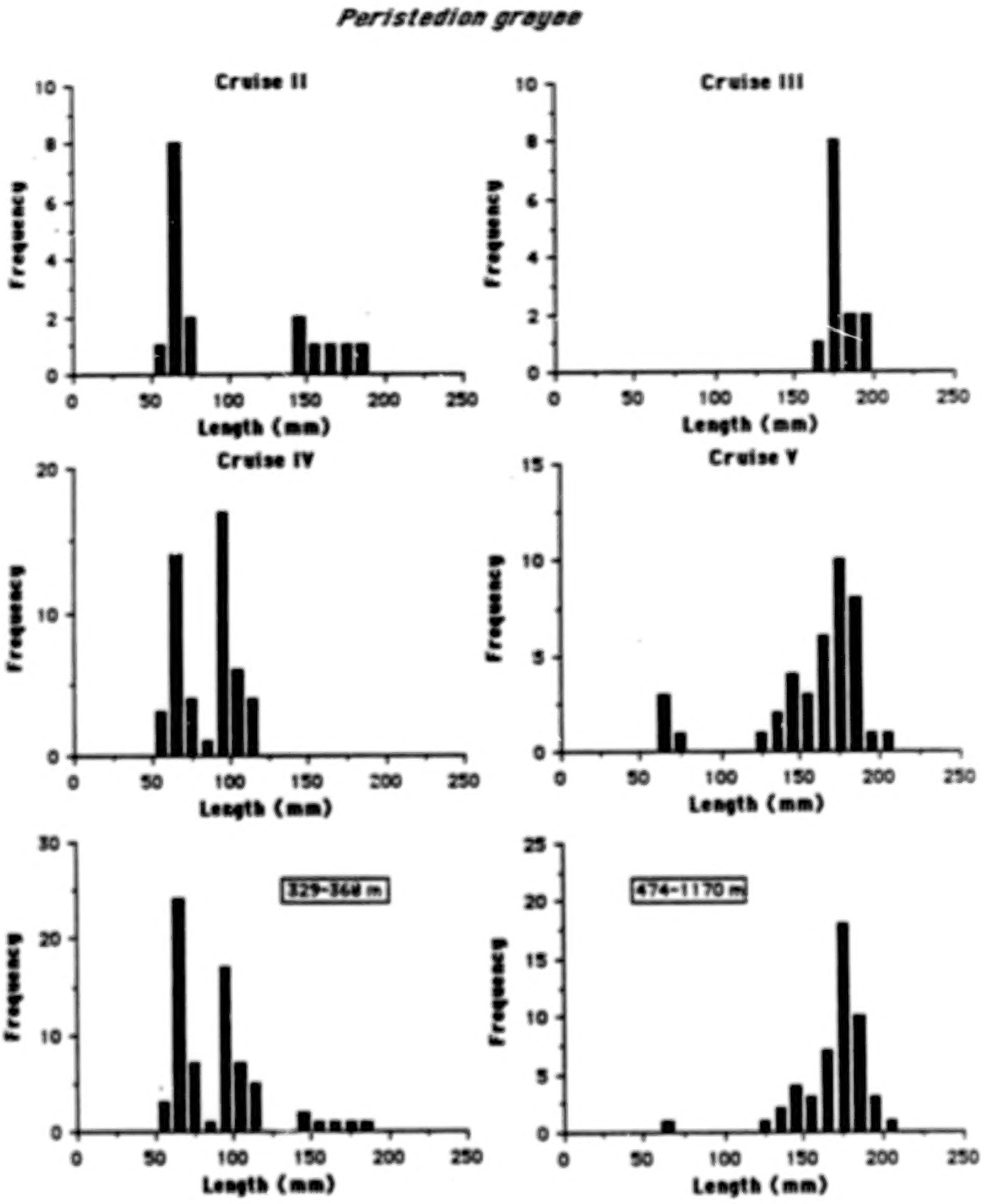

Figure 4-152. Frequency histograms for total lengths of Peristedion grayae from individual cruises.

5.0 BENTHIC PHOTOGRAPHY RESULTS

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5.0 BENTHIC PHOTOGRAPHY RESULTS

All planned photography transects were successfully completed at 60 stations. Four categories of subjects were analyzed in the photographs: lebensspuren (tracks, trails and impressions left by animals), consolidated materials, man-made artifacts, and megafauna. The total number of photographic samples and area analyzed for lebensspuren features (including consolidated materials and artificats) and biota for Cruises II-V appears in Table 5-1. It will be noted in Table 5-1 that the sample sizes differ between the lebensspuren and biota categories, even on the same transects. This difference is because many of the photographs that were of sufficient quality to identify megafaunal biota were not of sufficient resolution to identify lebensspuren categories with certainty.

Table 5-1. Total area surveyed by benthic photography, Cruises II-V.

	Lebensspuren		
	Cruise 2	Cruise 3	Total
Number of Frames	1275	1046	2321
Total Area (m^2)	3469	3100	6569

	Biota				
	Cruise 2	Cruise 3	Cruise 4	Cruise 5	Total
Number of Frames	1279	2328	3126	2414	9,147
Total Area (m squared)	3485	6709	7398	6988	24,590

5.1 LEBENSSPUREN

Lebensspuren features documented on the surface of the bottom sediments were observed at all benthic photography stations. These features, caused by the movements of animals living on or below the sediment's surface, were the most abundant category of any observations represented in benthic photographs. Lebensspuren classification for this study followed Ewing and Davis (1967) and used five of the six major lebensspuren groups described in that study including ridges, lumps, grooves, depressions, and sculptured strips. These major categories were subdivided by two additional levels of hierarchy as shown in Volume III, Appendix D1. permitting fairly distinct morphological descriptions of all lebensspuren features. Additionally, a large data base was created containing areas and/or length measurements of most lebensspuren features. These data can be later utilized for investigations of long-term changes in lebensspuren characteristics and may provide clues to associations of specific animal taxa and lebensspuren features.

General descriptions and densities of lebensspuren features documented at each station appear below.

5.1.1 STATION SUMMARIES

Lebensspuren analyses were based upon photography taken during Cruises II and III, only. Summaries of the number of frames taken on Cruise II that were suitable for analysis, the total areas sampled by these frames and their mean depth is shown by Table 5-2. A corresponding results summary (density of the various features by station) is shown in Table 5-3. The same information is provided for Cruise III in Tables 5-4 and 5-5, respectively. Detailed supportive data can be found in Appendix D1-3.

5.1.1.1 Cruise II West Transect

Station W1

All five Western Transect stations were photographed only during Cruise II. Station W1 lebensspuren analyses included a total area of 261 m^2 (Table 5-2). Total lebensspuren density for this station was 182,464 features/ha (Table 5-3). The most abundant lebensspuren type was "groups of depressions" represented by a total density of 167,460/ha which also represented the most abundant lebensspuren type at any of the 15 stations sampled during Cruise II. The vast majority of depression groups (165,388/ha) were characterized by a single type, described as a single row of depresions arranged in a partial circle. It is not known what organism produced this feature, but the very high density of the feature

5-2. Design table for Cruise II benthic photography lebensspuren.

STATION:	W1	W2	W3	W4	W5	Total
Number of frames	97	92	49	99	99	436
Area (m squared)	260.6	248.8	94.6	223.3	286.9	1114.2
Mean depth (m)	366	604	814	1396	2456	

STATION:	C1	C2	C3	C4	C5	Total
Number of frames	79	42	100	99	99	419
Area (m squared)	190.1	117.9	338.6	230.6	262.6	1139.7
Mean depth (m)	358	587	798	1420	2436	

STATION:	E1	E2	E3	E4	E5	Total
Number of frames	90	34	99	98	99	420
Area (m squared)	303.7	130	304.4	244.1	233.3	1215.5
Mean depth (m)	347	612	849	1322	2893	

Table 5-3. Lebensspuren major category densities (no./hectare) Cruise II stations.

STATION:	W1	W2	W3	W4	W5	Total
Individual ridges	0	121	317	2,015	4,914	1,723
Solitary lumps	3569	11,857	1903	5329	5124	6031
Sets of lumps	0	0	423	179	0	72
Individual grooves	3377	5306	32,886	54,816	2510	16,398
Sets of grooves	1036	3618	0	627	1464	1553
Solitary depressions	7022	62,784	27,176	17,018	22,760	27,240
Groups of depressions	167,460	21,544	2221	269	0	44,222
Strip of adjacent depressions	0	0	0	0	0	0
Total	182,464	105,229	64,926	80,253	36,771	97,239

STATION:	C1	C2	C3	C4	C5	Total
Individual ridges	53	764	384	87	267	281
Solitary lumps	6786	12,218	1949	7069	1638	4782
Sets of lumps	0	0	59	87	724	202
Individual grooves	210	12,897	10,986	2689	24,982	10,932
Sets of grooves	0	2461	295	0	2018	807
Solitary depressions	21,305	46,581	47,814	12,057	67,291	40,519
Groups of depressions	9363	10,012	13,231	347	30,770	13,688
Strip of adjacent depressions	0	0	207	0	1028	298
Total	37,717	84,931	74,926	22,336	128,717	71,509

STATION:	E1	E2	E3	E4	E5	Total
Individual ridges	0	3461	493	205	22,374	4829
Solitary lumps	3095	4999	3088	1639	11,702	4656
Sets of lumps	0	154	230	205	643	239
Individual grooves	1844	1461	25,033	33,470	4072	14,389
Sets of grooves	0	1077	427	614	3086	938
Solitary depressions	32,499	33,453	32,293	15,199	29,104	28,424
Groups of depressions	128,614	2384	6669	492	3086	34,750
Strip of adjacent depressions	99	0	0	0	0	25
Total	166,151	46,988	68,233	51,823	74,067	88,249

Table 5-4. Design table for Cruise III benthic photography lebensspuren.

STATION:	C1	C6	C2	C3	C7	C8
Number of frames	98	101	100	100	92	60
Area (m squared)	259.6	338	300.7	257	240	151
Mean depth (m)	353	525	629	866	950	1098

STATION:	C9	C4	C10	C11	C5	C12	Total
Number of frames	89	87	98	96	57	68	1046
Area (m squared)	274.9	279	313.6	272	175.8	238	3100
Mean depth (m)	1325	1408	1605	2074	2401	2882	

Table 5-5. Lebensspuren major category densities (no./hectare) Cruise III stations.

STATION:	C1	C6	C2	C3	C7	C8
Individual ridges	231	798	1231	1050	1167	2320
Solitary lumps	6317	16,256	16,031	2411	3666	1193
Sets of lumps	0	0	100	0	0	0
Individual grooves	31,241	1537	16,098	11,201	36,661	3845
Sets of grooves	77	680	1330	1556	167	66
Solitary depressions	35,555	101,944	116,111	124,654	31,537	8817
Groups of depressions	2542	23,801	25,078	13,885	6624	0
Strip of adjacent depressions	0	0	0	0	0	0
Total	75,964	144,016	175,908	154,758	79,822	16,242

STATION:	C9	C4	C10	C11	C5	C12	Total
Individual ridges	4947	3800	5295	4296	341	6679	2742
Solitary lumps	3747	4087	36,102	1652	1024	6091	9313
Sets of lumps	73	0	32	37	0	42	26
Individual grooves	1237	717	2137	1836	398	10,417	9674
Sets of grooves	0	0	0	441	341	1176	503
Solitary depressions	25,391	25,417	42,226	25,737	44,833	26,799	54,241
Groups of depressions	0	789	510	330	35,218	1638	9180
Strip of adjacent depressions	0	0	0	0	0	0	0
Total	35,394	34,810	86,301	34,328	82,157	52,842	85,679

suggests extensive biological activity probably by a specific type of organism.

Four other categories were recorded at this station: solitary lumps with 3569 features/ha; individual grooves with 3377/ha; sets of grooves at 1036/ha; and solitary depressions represented by 7022/ha (Table 5-3). Two of these groups, individual and sets of grooves indicated motile organisms. The most abundant solitary groove type was described as short, narrow and straight. These grooves are most probably produced by crab legs, either due to the crab walking or possibly resulting from feeding behavior. The crab, Lyreidus hairdii was the dominant decapod crab obtained in trawls at this station with a weighted density of 11/ha (Appendix C2-3).

Two types of groove sets were recorded and were caused by echinoderms, one type was asteriod-shaped impressions representing 230/ha, and the other distinctly ophiuroid-shaped impressions with a density of 384/ha.

Solitary depressions were equally distributed between deep and shallow depressions (probably indicating age) with 3031 and 3991 features/ha, respectively.

Station W2

Total lebensspuren density from analyses of 248.8 m^2 at Station W2 was 105,229/ha. The dominant lebensspuren feature was the category solitary depressions with 62,784/ha. These depressions were divided primarily between deep depressions (35,090/ha) and shallow, with 26,810/ha. The deeper depressions likely indicate more recent activity. Groups of depressions were present at the relatively high density of 21,544/ha, a value but significantly lower than observed at Station W1.

Solitary lumps were the second most abundant lebensspuren group at W2 with 11,857 features/ha. The majority of these features (8682/ha) were described as excavated sediment lumps adjacent to burrows. Other types of solitary lumps included a total of 925 lumps of probable holothurid fecal deposits although no holothuroids were captured in the trawl at Station W2. However, the holothuroid Mesothuria lactea was obtained on the other two transects at the same depth (Stations C2 and E2; Appendix C2-3).

Remaining lebensspuren categories included: a very low density (121/ha) of individual ridges; individual grooves (5306/ha the dominant type being closely spaced and almost certainly decapod tracks), and sets of grooves (3618/ha). A portion of these sets of grooves (804/ha) were produced by burrowing organisms which feed on the surface of the sediment producing a variety of grooves originating from a central point.

Station W3

At Station W3, total lebensspuren density from analyzed frames occupied an area of 94.6 m^2, which was lower than observed at shallower Stations W1 and W2 (64,926 features/ha). The most numerous feature type at W3 was individual grooves at 32,886/ha. Within this category, the dominant classification by far (21,889/ha) was short, narrow, closely-spaced grooves, probably representing decapod tracks.

Only one other lebensspuren category was represented by a noteworthy density. Solitary depressions were observed at an overall density of 27,176/ha, the majority of these (21,149/ha) being shallow depressions indicating a greater age of the structures compared to a density of only 5922/ha for deep depressions.

Four other lebensspuren groups were represented, but at relatively low densities. These were individual ridges with only 317/ha observed, sets of lumps at 423/ha, probably due to a chance arrangement of the more common solitary conical lumps (represented by a density of 1903/ha), and groups of depressions arranged in a partial circle observed at a density of 2221/ha.

Station W4

This station showed an overall increase in total lebensspuren density (80,253/ha) compared to Station W3 but had fewer features than Stations W1 and W2 (Table 5-3). The total area analyzed for lebensspuren features at W4 was 223.3 m^2. The dominant feature type was again individual grooves attributable to decapod tracks (54,816 grooves/ha). Interestingly, very few decapods were captured in the trawl at Station W4, although one Geryon quinquedens, a very likely track maker, was taken. An overall weighted density of only eight decapods/ha, including both crabs and shrimp, were trawled at this station.

Solitary depressions were represented by 17,018 features/ha, the great majority of these being shallow depressions (15,674/ha compared to only 1299 deep depressions/ha). Other lebensspuren categories occurred at relatively low densities, including individual ridges with 2015 features/ha, solitary lumps and sets of lumps with 5329 and 179/ha, respectively, and sets of grooves with 627/ha. Groups of depressions were represented by a density of only 269/ha, much lower than the three shallower stations of the Western Transect.

Station W5

This station, at a depth of 2456 m, had the lowest overall lebensspuren density at 36,771 features/ha. The most abundant lebensspuren type recorded from the total area of 296.9 m^2 analyzed was solitary depressions at a density of 22,760 depressions/ha. Of these, nearly all (21,993/ha) were classified as shallow depressions indicating burrowing activity in the more distant past and/or a more rapid infilling of excavated burrows. Only 732 depressions/ha were classified as deep depressions which had not been filled in by sediments or smoothed over.

Other categories of major lebensspuren types were represented by very low densities, all less than 5000/ha. However, the category of individual ridges had the highest density of the Western Transect at Station W5 with 4914 ridges/ha. These ridges indicated a burrowing organism which moves just below the surface of the sediment leaving an elevated ridge projecting above the surrounding bottom. Three other lebensspuren categories were recorded including solitary lumps at 5124/ha, individual grooves at 2510/ha and sets of grooves with 1464/ha.

Western Transect Overview

Figure 5-1 illustrates overall lebensspuren density for all 15 Cruise II stations by depth. The Western Transect exhibits a general decrease in total lebensspuren density with depth with the exception of Station W4 where the density increased to 80,253 features/ha before decreasing to the

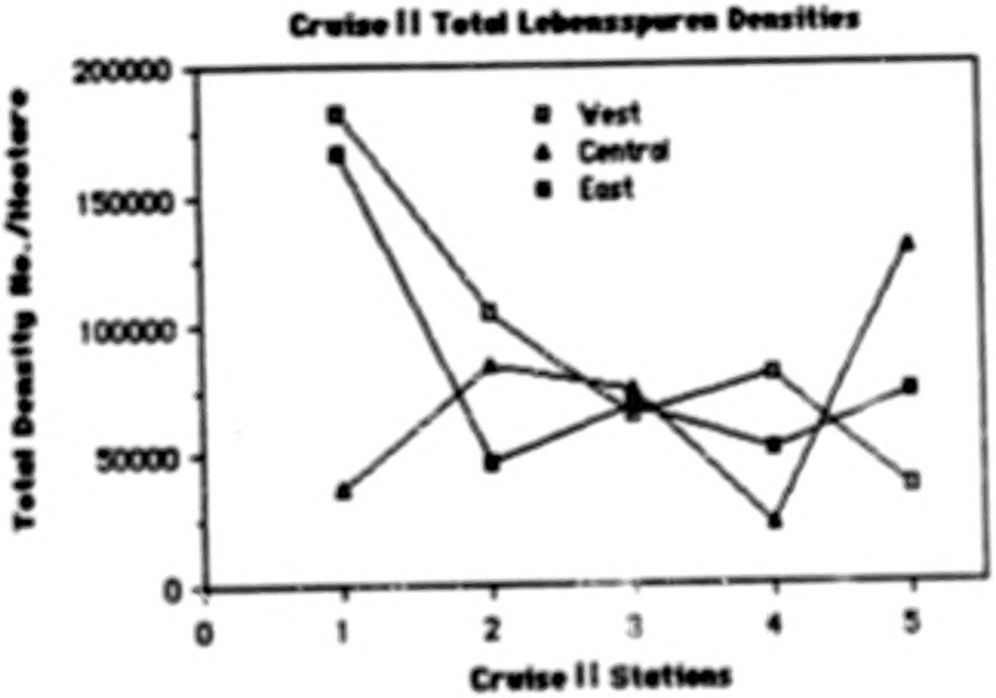


Figure 5-1. Total lebensspuren densities for Cruise II stations.

lowest of the transects at Station W5 with an overall lebensspuren density of 36,771/ha.

Figure 5-2 presents the overall density of all eight major lebensspuren categories for each of the Cruise II stations separately, the Western Transect being in the first column in order of increasing depth. Figure 5-3 graphs each major lebensspuren category separately for all 15 Cruise II stations to illustrate how stations and transects related to each other within a specific lebensspuren type. One obvious trend was that shown by the dominant feature type on the Western Transect, groups of depressions which had a very high density of 167,460/ha at Station W1, but had decreased to 0 at Station W5.

The second ranked lebensspuren feature category, solitary depressions (those not arranged in any perceptible pattern), peaked in density at Station W2. The general trend was similar to both the Eastern and Central Transects showing a sharp drop in density between Station 3 to 4 and an increase from Station 4 to 5.

Individual grooves were also a significant contribution to the overall lebensspuren density on the Western Transect, having a peak at Station W4. The increase in this particular feature with depth resulted in the reversal of the general trend of decreasing total lebensspuren density with depth. Figure 5-3 illustrates the peak density of individual grooves occurred at Station W4 and this peak represented the highest value from all 15 Cruise II stations.

Although sets of grooves did not represent a significant contribution to total lebensspuren density at any station, Station W2 exhibited another maximum for all Cruise II stations with a density of 3618/ha. The pattern for distribution of groove sets appears to be similar for all three Cruise II transects--a density peak at Station 2, a minimum at Station 3 and a rise to a secondary peak at Station 5.

Individual ridges and sets of lumps were found at very low densities throughout the Western Transect. Solitary lumps exhibited a peak in density at Station W2 and a minimum density at Station W3.

There were no recorded strips of adjacent depressions representing holothuroid trails in any of the Western Transect stations; however, there were a few larger holothuroids collected at Station W5 in the trawl (Appendix C2-3). The two genera known to produce a visible trail,

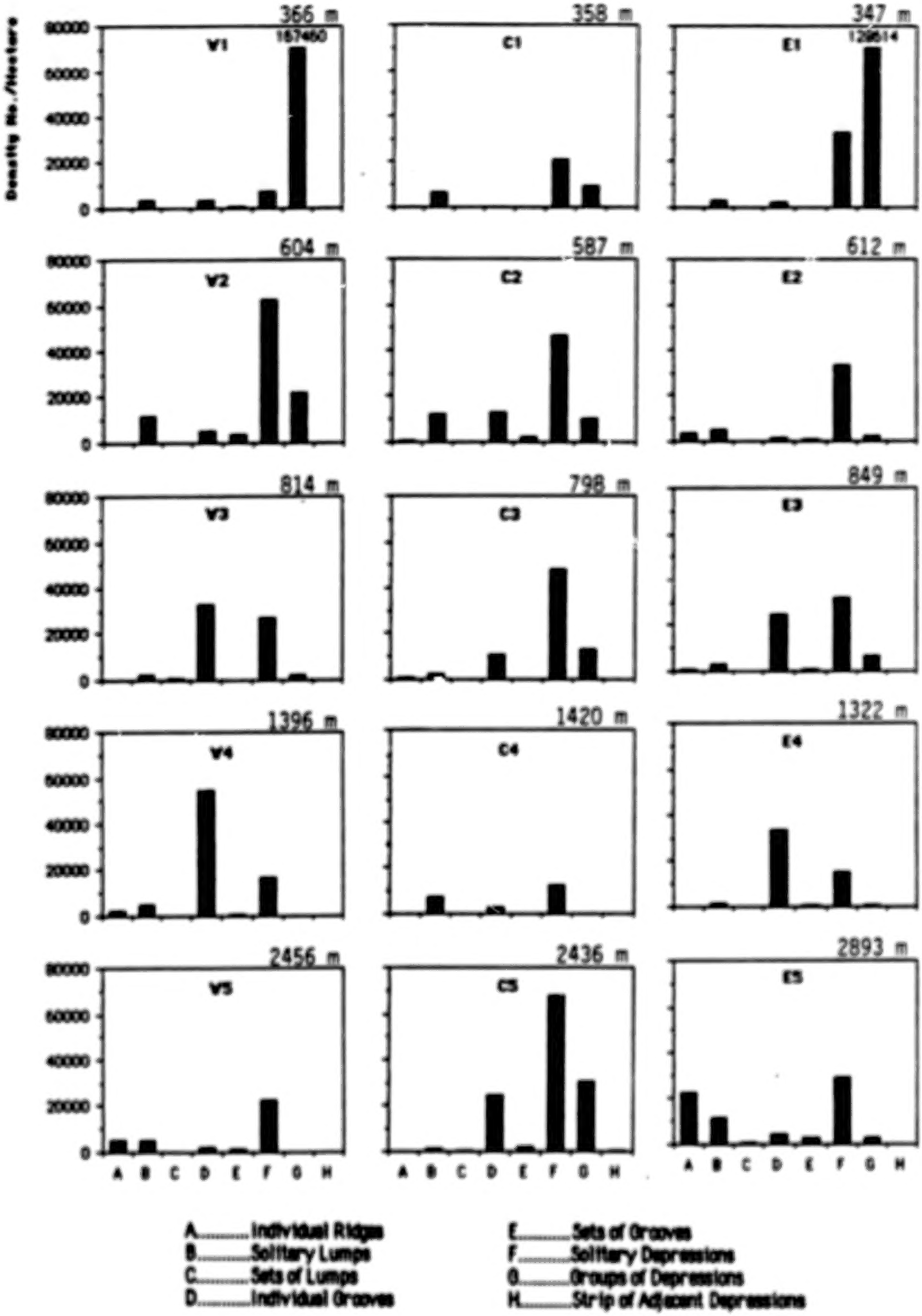
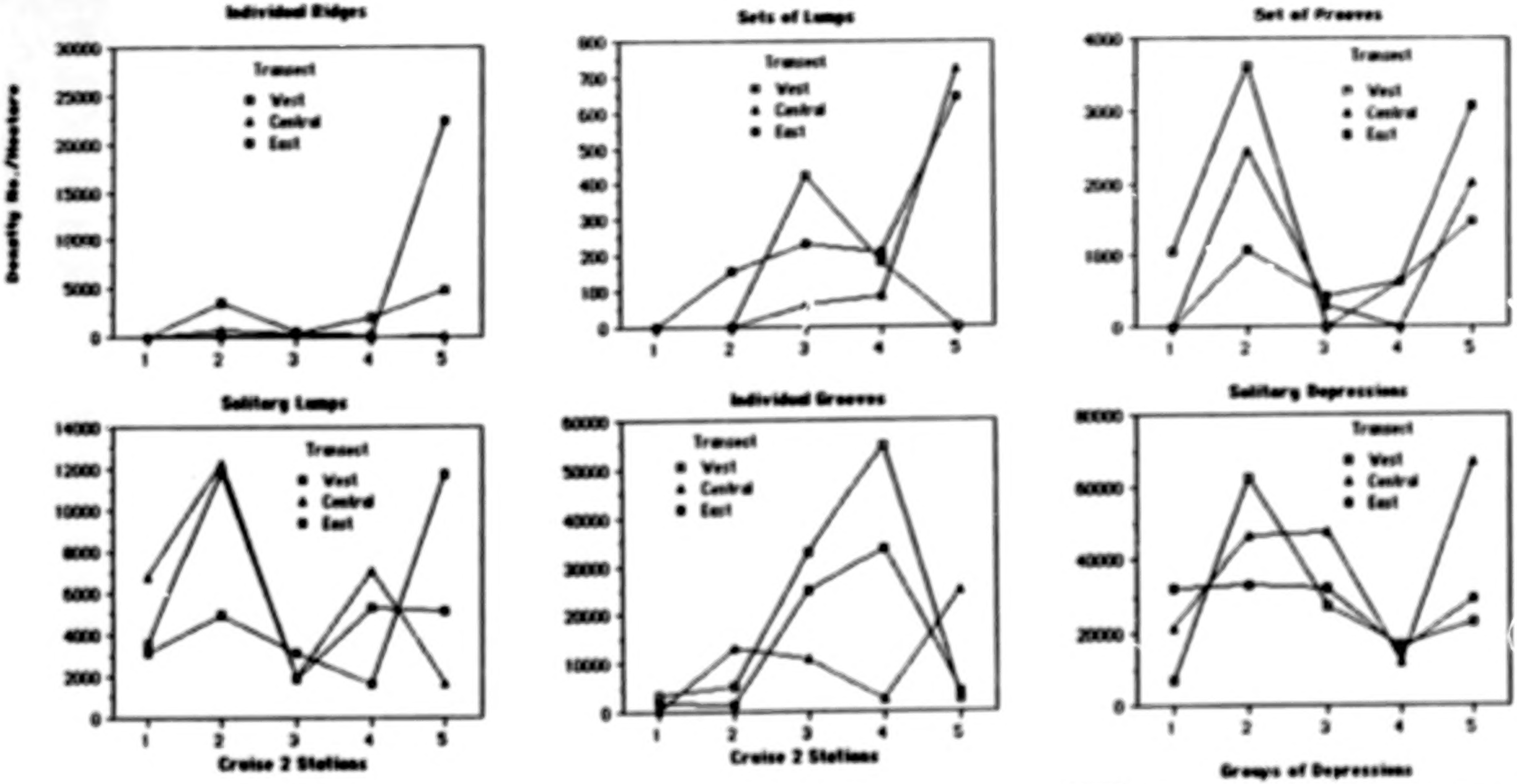


Figure 5-2. Major lebensspuren category densities by station, Cruise II.



Cruise II Station Depths

Station	West	Central	East
1	366	358	347
2	604	587	612
3	814	798	849
4	1396	1420	1322
5	2456	2436	2893

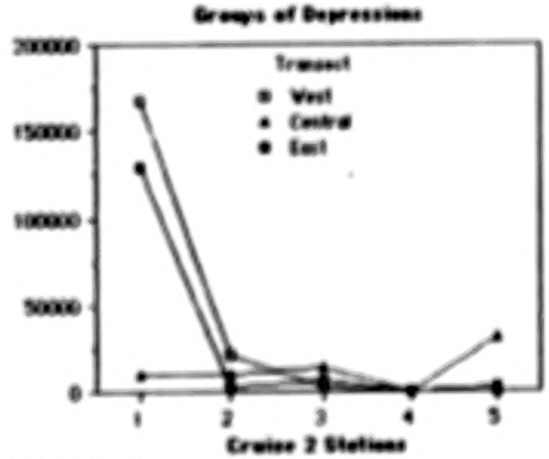


Figure 5-3. Cruise II station densities for separate major lebensspuren categories.

Benthodytes, and Psalopatides were not captured in trawls or recorded in benthic photography transects at any Western Transect station.

5.1.1.2 Cruise II Eastern Transect

Station E1

The five stations of the Eastern Transect, E1-E5 were photographed during Cruise II, Station E1 being the shallowest at a depth of 347 m. A total area of 304 m^2 at E1 was analyzed for lebensspuren features resulting in the very high overall lebensspuren density of 166,151/ha, surpassed only by Station W1 with 182,464 features/ha, also sampled during Cruise II.

Similar to Station W1 and unlike the remaining Cruise II stations, the dominant lebensspuren featured at Station E1 was the category "groups of depressions" represented by a density of 128,614/ha. Sediment grain size analyses from both Stations W1 and E1 resulted in substantial proportions of sand, the only Cruise II stations with more than 35% sand.

Three other major lebensspuren categories were represented at E1 by a density of more than 1000 features/ha. The second ranked category was solitary depressions (32,499 features/ha). This feature was the dominant type in most all other Cruise II stations. These depressions appeared to be largely deep, recently active burrows (27,461/ha compared to 5005/ha for shallow depressions). Other categories represented included solitary lumps and individual grooves, with 3095 and 1844 features/ha, respectively. Very few (99/ha) tracks of holothuroids (represented as strips of adjacent depressions) were observed.

Station E2

Station E2 was at a depth of 612 m and analyzed frames constituted a total bottom area of 130 m^2. Sediment grain size was also heavily influenced by the sand fraction, similar to Station E1. Overall lebensspuren density was 46,988 features/ha, the lowest on the Eastern Transect.

The dominant lebensspuren category was solitary depressions, the greater proportion described as shallow (18,918/ha) as opposed to deep depressions (14,535/ha). The second ranked feature type was solitary lumps with a density of 4999/ha. Approximately one-third of these had an apical round hole (1154/ha compared to 3076/ha without a hole) suggesting an active inhabitant.

Other features represented at Station E2 made up a much smaller proportion of the total lebensspuren abundance. These included individual ridges with 3461 features/ha, individual grooves with a density of 1461/ha and sets of grooves with 1077/ha.

Station E3

Lebensspuren analyses at Station E3, at a mean depth of 849 m, resulted in an intermediate overall lebensspuren density of 68,233 features/ha. A total bottom area of 304 m^2 was analyzed.

The first ranked lebensspuren category was again solitary depressions which had a density very similar to that observed at Station E2. However, this category was closely followed in abundance at E3 by individual grooves which had a density of 25,033/ha. The majority of these grooves were described as short, narrow, and straight, probably resulting from decapod movements across the sediment although decapod density resulting from trawling was quite low in comparison to the two previous stations, E1 and E2. The large crab Geryon was captured here, but at a density of only 2/ha.

Other lebensspuren categories well represented at Station E3 included groups of depressions with 6669/ha, and solitary lumps with a density of 3088/ha.

Station E4

Station E4 was at a mean depth of 1322 m and a total area of 233 m^2 was analyzed for lebensspuren features. Total lebensspuren density was 51,823 features/ha, dominated by individual grooves which represented 33,470/ha of the total. Station E4 was the only Cruise II station dominated by the category of individual grooves. The majority of the grooves (28,667/ha) were short, narrow, and straight, similar to those observed at Station E3. Many large benthic decapods were well represented in trawl samples from Station E4, including the large crab Geryon known to leave visible short, narrow grooves in the sediment.

The second-ranked lebensspuren category was solitary depressions, dominated by the shallow variety (13,355/ha from a total density of 15,199). The only other category with a significant density was solitary lumps with only 1639 lumps/ha, most all of those (1065/ha) without a visible, apical, round hole.

Station E5

The deepest station of the Eastern Transect, which had a mean depth of 2893 m, was essentially off the continental slope due to the difficulty photographing the target depth located directly on the Florida Escarpment. Sediment grain size analyses indicated Station E5 had the lowest sand proportion and highest clay proportion of any of the Eastern Transect stations. Overall lebensspuren density was a relatively high 74,067 features/ha, second highest of the Eastern Transect.

The dominant feature type was solitary depressions, virtually all (28,247 of 29,104/ha) being classified as shallow, apparently filled in depressions. The second ranked feature category, individual ridges, was generally very rare throughout all other Cruise II stations. An unknown burrowing animal produced narrow grooves with a random path having a density of 18,517/ha. Coincidentally, a species of isopod, Aega sp., was captured in the trawl at Station E5 at a very high density of 992/ha and was found at extremely low densities at only three of the other Cruise II stations (Appendix C2-3).

Solitary lumps were well represented with a density of 11,702/ha but only a small portion of that density (1629/ha) was represented by conical lumps common at other stations. The remainder represented fecal material of holothuroids (Appendix D1-3). One type, with a total density of 6258/ha, was described as an elongate sculptured lump resembling a coiled rope lying on its side. The other similar material (having a density of 3515/ha) was described as a sculptured elongate lump resembling a pile of uncoiled rope. The actual traces of holothuroids which would have been classified as strips of adjacent depressions were not observed at this station, probably due to the fine texture of the sediment and its failure to preserve that type of impression.

Other lebensspuren categories representing a significant density included individual grooves with 4072/ha, and two other categories, sets of grooves and groups of depressions, both represented by a density of 3086 features/ha.

Eastern Transect Overview

Figure 5-1 shows total lebensspuren density by stations for each of the three Cruise II transects: West, Central and East. The Eastern Transect shows a sharp decrease in lebensspuren density below the shallowest Station E1, similar to the Western Transect but there is no consistent trend of decreasing density with depth. Station E2 had the lowest overall lebensspuren density of the five Eastern Transect stations. The combined lebensspuren density total for all Eastern Transect stations was 88,249 features/ha, intermediate to the totals of the Western and Central Transects.

The eight major lebensspuren categories are shown in histograms for the five Eastern Transect stations individually in Figure 5-2. Figure 5-3 plots densities of each lebensspuren category separately for all five stations of each transect in separate graphs. The most numerous category, groups of depressions, showed a similar pattern as the Western Transect: a very high peak occurred at the shallowest station at a depth of 347 m, and relatively low densities occurred throughout the other four stations. The second ranked category for the transect was solitary depressions. Stations E1-3 and E5 showed similar solitary depression densities, the lowest value for this category appearing at Station E4.

Individual grooves, the third most numerous major lebensspuren category on the Eastern Transect showed a similar distribution pattern to that previously described for the Western Transect. Individual groove densities were low at Stations 1 and 2, rose to a peak at Station 4 and decreased dramatically from Station 4 to 5.

Other lebensspuren features were not very abundant on the Eastern Transect with the notable exception of individual ridges discussed earlier. At Statin E5, a peak density of 22,374 individual ridges/ha is shown graphically in Figure 5-3. This value represented the highest density of all 15 Cruise II stations.

5.1.1.3 Central Transect Stations: Cruises II and III (by depth)

Station C1

Station C1, centered around a depth of 335 m, was photographed on three different cruises: Cruise I, II and III. Only during Cruises II and III, which utilized the LGL BUCS camera system were photographs obtained with sufficient information to allow quantitative analyses. A total area of 190.1 m^2 was analyzed from Cruise II and 259.6 m^2 from Cruise III (Tables 5-2 and 5-4).

Overall lebensspuren density was higher from Cruise III compared to Cruise II; 75,964 and 37,717/ha, respectively (Tables 5-3 and 5-5). The dominant category from both cruises was solitary depressions with 35,555/ha during Cruise III and 21,305 from Cruise II. The solitary depression types were nearly equally divided between shallow and deep during Cruise II (10,363 and 10,784/ha, Appendix D1-4), but the shallow type depressions were more numerous during Cruise III with 20,004 compared to 13,945/ha for deep solitary depressions. The midpoint of the two transects were relatively close together (separated by 2.22 km, Table 5-6) but even this small separation could have placed the transects into significantly different areas with slightly different sediment characteristics with different abilities to preserve or fill in depressions. However, the sediment grain size analyses did not show significant differences between the two cruises (Attachment Figs. 7-2 and 7-3).

Table 5-6. Distance between Central Transect station photo transects between Cruises II and III.

Station	Cruise II Depth	Cruise III Depth	Separation Distance (km)
C1	335	337	2.22
C2	589	668	2.95
C3	802	852	2.72
C4	1407	1390	4.54
C5	2433	2407	4.38

The second ranked lebensspuren feature at Station C1, individual grooves, was surprisingly higher in density by more than two orders of magnitude (31,241 compared to 210/ha) during Cruise III compared to Cruise II. The great majority of individual grooves recorded during Cruise III were categorized as short, narrow, closely spaced decapod tracks (23,074/ha). It was curious that more short grooves appearing to be decapod tracks were not recorded from Station C1 during Cruise II as there were similar numbers of large crabs captured in trawls during both of these two cruises at this station (Appendices C2-3 and C2-4).

Solitary lump density was virtually the same between the two cruises with 6786/ha recorded from Cruise II and 6317/ha on Cruise III. Individual ridges appeared in very low densities during both cruises with only 53/ha on Cruise II and 231/ha from Cruise III.

Depressions were dominated by solitary observations (21,305/ha during Cruise II and 35,555/ha during Cruise III). Depressions arranged in groups (single row in partial circle) were observed at considerably lower densities during both cruises. Cruise II with 9363/ha and 2542/ha during Cruise III.

Station C6

This station at a depth of 525 m was sampled only during Cruise III. A total area of 338 m^2 was analyzed with an overall lebensspuren desnity of 144,016/ha. Sediment characteristics were very similar to Station C1 but Station C6 had a drastically reduced density of individual grooves, 1537/ha as compared to 31,241 at Station C1 during Cruing III.

Solitary depressions exhibited the highest density at Station C6 with 101,944/ha. Depressions arranged in groups were the second ranked lebensspuren category with 23,801 depressions/ha. Solitary lumps were a visually important feature but occurred as the third ranked category at 15,256/ha, primarily due to their relatively large size. The lebensspuren categories representing motile biota, i.e., ridges and grooves showed very low densities.

Station C2

This station was sampled on the first three cruises with the results from Cruises II and III presented in the figures. A total area of 118 m^2 was analyzed from Cruise II and 300 m^2 from Cruise III. Again, the sediment grain size analyses for this station between the two different cruises were quite similar. In the photographs, the sediment's surface appeared to be very fine grained and almost flocculent, however, grain size analyses showed an increase in the sand fraction as compared to neighboring Stations C6 and C3. The photographic transect midpoints of Cruises II and III were separated by 2.95 km at depths of 587 and 629 m, respectively.

The dominant lebensspuren category for both cruises was solitary depressions, represented by densities of 45,581/ha during Cruise II and a substantially higher 116,111/ha during Cruise III. One taxa, the decapod crab Bathyplax typhla, frequently seen in benthic photographs, appeared to be a major contributor to the creation of solitary depressions as well as short individual grooves left behind as tracks. In several frames, B. typhla was photographed inside depressions with apparent tracks surrounding the burrow. This species was also captured in trawls at Station C2 during both Cruises II and III in the highest densities found at all Central Transect stations, 26 and 30/ha, respectively.

The second ranked category varied between cruises, during Cruise II individual grooves were represented by a density of 12,218/ha and during Cruise III the second ranked category was groups of depressions with a density of 25,073/ha. One other major category, solitary lumps, was represented during both cruises in significant density, Cruise III being greater than Cruise II.

Station C3

This station was also sampled during three cruises with quantitative data available from Cruises II and III. The sampling locations were separated by a distance of 2.72 km between these two sampling periods, Cruise II at a depth of 798 m and Cruise III at a depth of 866 m. Analyzed area from Cruise II included 339 m^2, and 257 m^2 was analyzed from Cruise III.

The overall lebensspuren density during Cruise III was more than double that of Cruise II, 154,758 features/ha compared to 74,926/ha, respectively. The bulk of this difference was due to a three-fold increase in the density of solitary depressions in Cruise III sample frames. Looking at the specific depression types, Cruise III solitary depressions were represented by a much higher density (by a factor of more than 3.7) of shallow depressions as compared to deep. During Cruise II, this relationship was reversed with deep, apparently active depressions, outnumbering shallow ones, but by only a small margin (35,090 compared to 26,810/ha). The remaining major lebensspuren types were very similar between the two cruises.

Station C7

Station C7, at a depth of 950 m was sampled only during Cruise III. A total area of 240 m^2 was analyzed for lebensspuren features. Overall lebensspuren density was 79,822/ha, a significant decrease from the previous two stations and very similar to Station C1. In general, Station C7 was very anomalous due to at least two extensive areas of apparent chemical influence on the color, texture and epifauna occurring on the surface layer of the sediment. Of particular note with regard to lebensspuren was the very high density of individual grooves, 36,661/ha, the highest of all Central Transect stations from both cruises, and also making this station the only one not dominated by the category of solitary depressions. The primary contributor to this higher density of individual grooves was a single feature described as rough broad grooves formed in this case by the surficial plowing of living vesicomyid clams. At least two species were represented, both of which were related to the bivalves in chemoautotrophic communities found in the Gulf of Mexico and at hydrothermal vents in the Pacific Ocean. Descriptions of these clam aggregations and their significance appeared in the previous Annual Report (LGL and Texas A&M 1986).

One other major lebensspuren category, solitary depressions, was represented by high densities (31,537/ha) at Station C7. This category was divided relatively equally between shallow and deep depressions, 17,164 and 14,081/ha, respectively.

Station C8

Station C8, sampled only during Cruise III at a depth of 1098 m, exhibited an overall lebensspuren density of 16,242 features/ha, the lowest of all Cruise III Central Transect stations. A total bottom area of 151 m^2 was analyzed from this station.

The dominant feature was solitary depressions with only 8817 depressions/ha which also represented the lowest density for this category from all Central Transect stations. Other categories represented included individual grooves with 3845/ha, individual ridges with 2,320/ha and solitary lumps with only 1193/ha. The sediment grain size distribution (Attachment Fig. 7-3) was very similar to that of Station C7 but this was the first station which did not have depressions arranged in regular patterns. No obvious deletion of invertebrate megafauna taxa occurred, compared to previously described shallower stations and Station C8 (Appendix C2-4) which would explain the lack of groups of depressions.

Station C9

This station was also sampled only during Cruise III and had a mean transect depth of 1325 m. Overall lebensspuren density was 35,394 features/ha. The dominant category by far was solitary depressions having a density of 25,391/ha. In general, the pattern and types of features observed were very similar to those noted at Station C8. Again, as at

Station C8, there were no groups of depressions and the other three lebensspuren categories observed at Station C9; individual ridges, solitary lumps, and individual grooves appeared in similar low densities as had been observed for Station C8.

Station C4

Station C4 was sampled during the first three cruises and processed quantitatively using samples from Cruises II and III. Total area analyzed included 231 m^2 from Cruise II at a mean depth of 1420 m, and 279 m^2 from Cruise III for samples having a mean depth of 1408 m. The photo transect midpoints from the two cruises were separated by a relatively large distance of 4.54 km. Although the sediment grain size analyses were generally similar between the two cruises, there was a slight increase in the proportion of coarser grained sand in Cruise II samples compared to Cruise III (Attachment Figs. 7-2 and 7-3). Overall lebensspuren density was higher during Cruise III with 34,810 features/ha compared to 22,236/ha during Cruise II.

Lebensspuren density by categories during Cruise III was very similar to that observed for previous Stations C9 and C8 except for the addition of a very low density of groups of depressions at only 789/ha. The dominant category during both cruises was solitary depressions, the higher density of 25,417/ha found during Cruise III, about half that density seen during Cruise II (12,057/ha). One dominant species having an apparent significant effect on lebensspuren features was the holothuroid *Peniagone* sp. This small sea cucumber (2-3 cm) was seen in virtually every photograph from this station. Although not classified as individual lebensspuren features, very small lumps were seen in most all frames which appeared to be related to the abundance of these holothuroids.

Station C10

Station C10 was sampled only during Cruise III at a mean depth of 1605 m with a total analyzed area of 314 m^2. The overall lebensspuren density was in the upper range of Central Transect stations with 86,301 features/ha. The general appearance of the sediment surface was quite unusual. The bottom was highly textured throughout most of the transect, in some frames looking like a coarse gravel. The texturing throughout the area appeared to be due to strong bottom currents scouring away the finer surficial sediments. In many frames, there were recognizable ripple marks in the sediments. Unfortunately, box cores were not obtained from this station due to the coarse or compact nature of the sediments. The box cores attempted at this station could either not penetrate through the coarse sediment or the corers could not close completely when tripped and lost most or all the sample on the way to the surface. Presumably the sediment grain size analyzes would have resulted in a significantly higher sand proportion compared to the other Central Transect stations. Visually at least, Station C10 was by far the roughest in texture and showed the most prominent signs of strong bottom water currents in comparison to any other Central Transect station.

Two categories dominated the lebensspuren counts, solitary depressions with a density of 42,226/ha and solitary lumps with 36,102/ha. Solitary depressions were the dominant lebensspuren features but the second ranked category type, solitary lumps, were also very prominent appearing in most every frame. The majority (26,694/ha) were conical lumps which exhibited an apical round hole indicating an active inhabitant. This density represents the highest of all Central Transect stations by more than an order of magnitude. An additional 5900/ha were classified as conical lumps without apical round holes, even this figure approximately doubles that of any other station. Very few animals were captured in the trawl at this station and none of those that were obtained suggested a probable animal responsible for creating the high density of these lumps.

Two other lebensspuren categories were represented by significant densities at Station C10; individual ridges with 5294/ha and individual grooves with 2137/ha. Both of these densities were comparable to adjacent Stations C9 and C11.

Station C11

This station was sampled only during Cruise III at a depth of 2074 m. The total area analyzed for lebensspuren features was 273 m^2. Overall lebensspuren density was relatively low at 34,328 features/ha, reduced from the higher density seen at the next shallower Station C10 but very similar to Stations C9 and C4. The sediment grain size distribution at Station C11 was somewhat confused, with a variety of sediment types represented in the different box core replicates (ranged from clay to silty clay to sand-silt-clay mixes). Visually, the bottom texture appeared very coarse in some places, but the coarseness seemed to be on the surface of the sediment only. The patchiness of coarse grained surficial sediments could have accounted for the variability seen in box core grain size analyses.

The great majority of records were solitary depressions (25,737/ha), most of those described as shallow depressions (24,599/ha) compared to deep with a density of only 1138/ha. The only other significant major lebensspuren category was individual ridges represented by a density of 4296/ha.

Station C5

Station C5 was the deepest station sampled during all of the first three cruises. The separation of the photographic transect midpoints between the two data-producing cruises was 4.38 km. The mean depth during Cruise II was 2436 m with an analyzed area of 263 m^2. During Cruise III the mean depth was 2401 m from an area of 176 m^2. Sediment grain size analyses results varied only slightly between the two cruises with all replicates falling within the silty-clay size classification.

Lebensspuren density for this station varied considerably between cruises. Cruise II showed a very high overall density of 128,717 features/ha and 82,157/ha were recorded from Cruise III. Station C5 was the only one of multiply sampled Central Transect Stations C1-5 where Cruise II overall lebensspuren density surpassed that of Cruise III. During both cruises, the two dominant lebensspuren categories were solitary depresions (ranking first) and groups of depressions (ranking second). The category of solitary depressions represented a slight increase in density compared to neighboring stations but the high densities observed for groups of depressions (30,770 and 44,833/ha, Cruises II and III, respectively) represented an extreme increase from other deep Central Transect stations and were the highest recorded for this category for all Central Transect stations from both cruises.

The third ranked major lebensspuren category during Cruise II, individual grooves with a density of 24,982/ha, was virtually absent during Cruise III (only 398/ha). No obvious explanation for this discrepancy is evident in invertebrate densities resulting from trawl samples taken during the two cruises at this station (Appendicies C2-3 and C2-4). In contrast, species capable of producing grooves (holothuroids, ophiuroids, etc.) were actually more abundant during Cruise III than Cruise II.

Station C5 sampled during Cruise II was one of the few stations where adjacent strips of depressions were recorded. This type of feature is produced by the movement of holothuroids and is one of the few which can be attributed to a specific type of animal.

Station C12

Station C12 was the deepest station of the Central Transect with a mean depth of 2882 m and was sampled only during Cruise III. A total area of 238 m^2 was analyzed for lebensspuren resulting in a moderate overall lebensspuren density of 52,842 features/ha. The sediment surface appeared very fine grained in the photographs but the grain size analyses resulted in the highest sand and lowest clay proportion of all Cruise III stations. What appeared to be fine grained sediments in the photographs may have been limited to a thin layer on the surface of the substrate.

The dominant lebensspuren category was solitary depressions with the great majority of those classified as shallow (23,229/ha) as opposed to deep depressions (3570/ha). The second ranked category was individual grooves with a density of 10,417/ha. This classification was primarily divided between two types of grooves both of which were produced by the plowing action of an animal moving across the bottom. One classification was narrow smooth grooves (4537/ha) and a second classification of broad sculptured grooves (4327/ha) produced by a larger animal causing ridges of sediment to form paralleling ridges along the length of the groove. The latter classification was rarely seen at any of the other shallower Central Transect stations.

Individual ridges and solitary lumps were also well represented by densities of 6679 and 6091 features/ha, respectively.

Central Transect Overview for Cruises II and III

Total lebensspuren densities for all 12 Cruise III stations are shown in Figure 5-4 and combined Central Transect stations from both Cruises II and III in Figure 5-5. Both cruises show a similar pattern of density with increasing depth although there is some variation between cruises. Total densities from Stations C1-C4 were all lower during Cruise II compared to Cruise III but Station C5 total density was higher during Cruise II.

Maximum lebensspuren density occurred at Station C2 during both cruises. The peak density of 175,980 lebensspuren features/ha occurred during Cruise III. Unlike Stations E1 and W1 of the Eastern and Western Transects, the shallowest station of the Central Transect, Station C1 was relatively low in overall lebensspuren density. The minimum total lebensspuren density on the Central Transect appeared at Station C8 (16,242/ha) at a depth of 1098 m. With increasing depth below Station C8, total lebensspuren density oscillated at a moderate level between 35,000-86,000 features/ha.

Figure 5-6 presents histograms of all six major lebensspuren categories for each station separately, arranged in columns in order of increasing depth. Density of features by depth from all Cruise III stations is shown for each lebensspuren category in separate graphs in Figure 5-7. The most numerous feature type, solitary depressions (overall density of 54,241/ha), had a pattern of distribution by depth similar to that of two other category types, groups of depressions and sets of grooves (Fig. 5-7). The shallowest station, C1 had relatively low densities for these three categories, but levels increased to maximums for the transect at Stations C2 or C3 (629 and 866 m), and then dropped sharply at Station C8 at a depth of 1098 m. The category of groups of depressions showed a substantial increase from surrounding stations at the deep Station C5 (2401 m) representing the highest density of the transect for this category. A sharp increase was also seen for sets of grooves at the deeper Station C12 (2882 m).

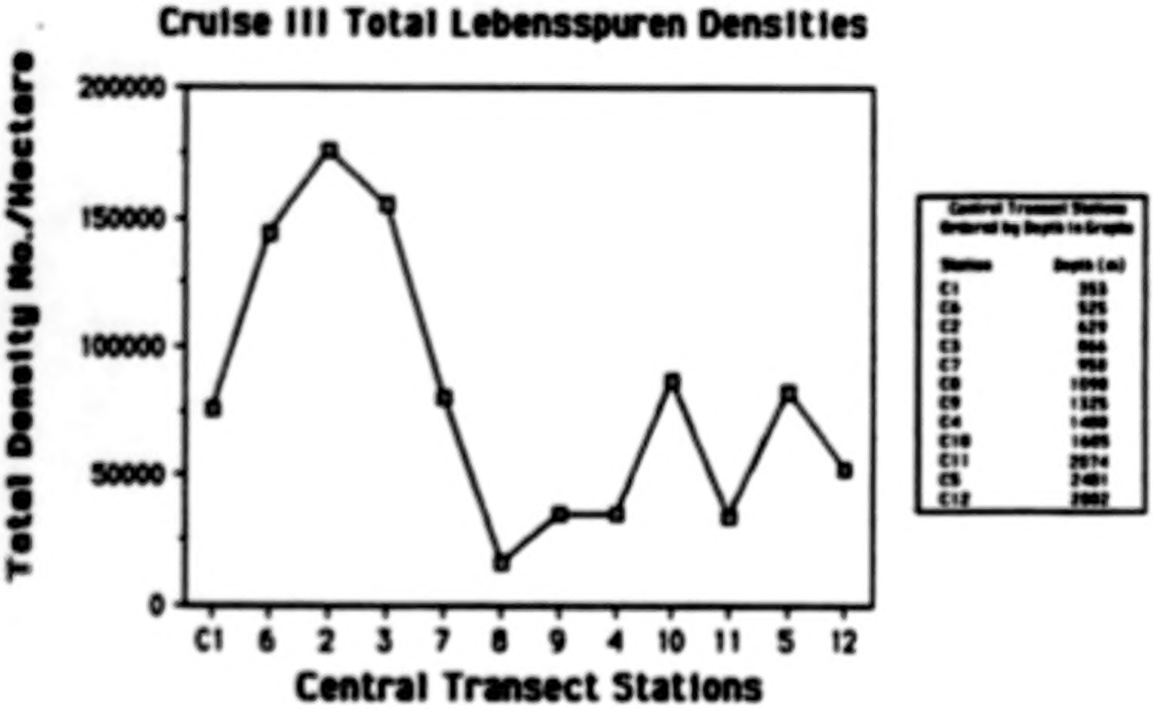


Figure 5-4. Total lebensspuren densities for Cruise III stations.

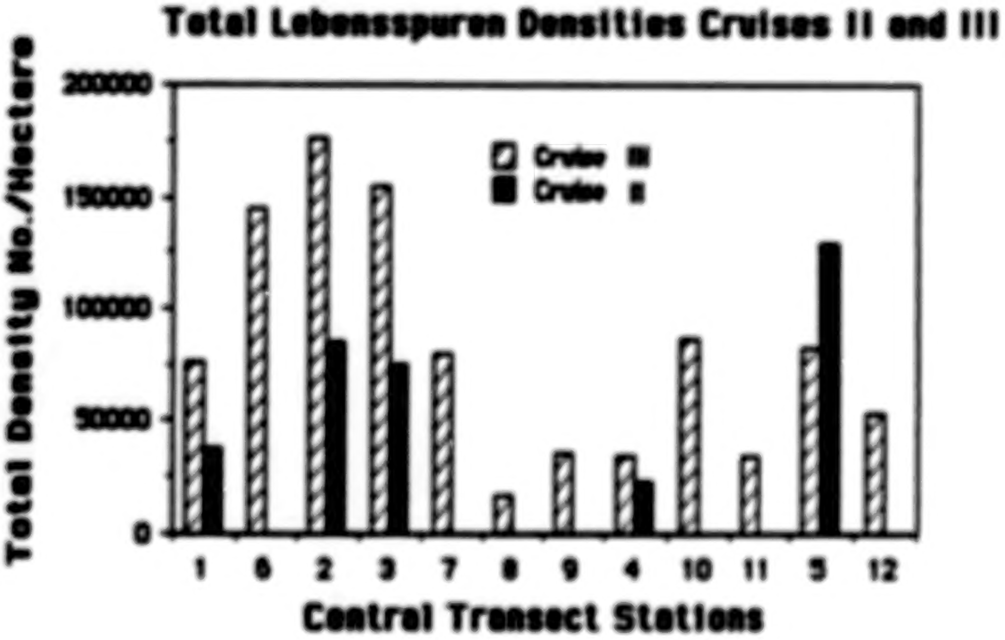


Figure 5-5. Total lebensspuren densities for Cruise II and III stations.

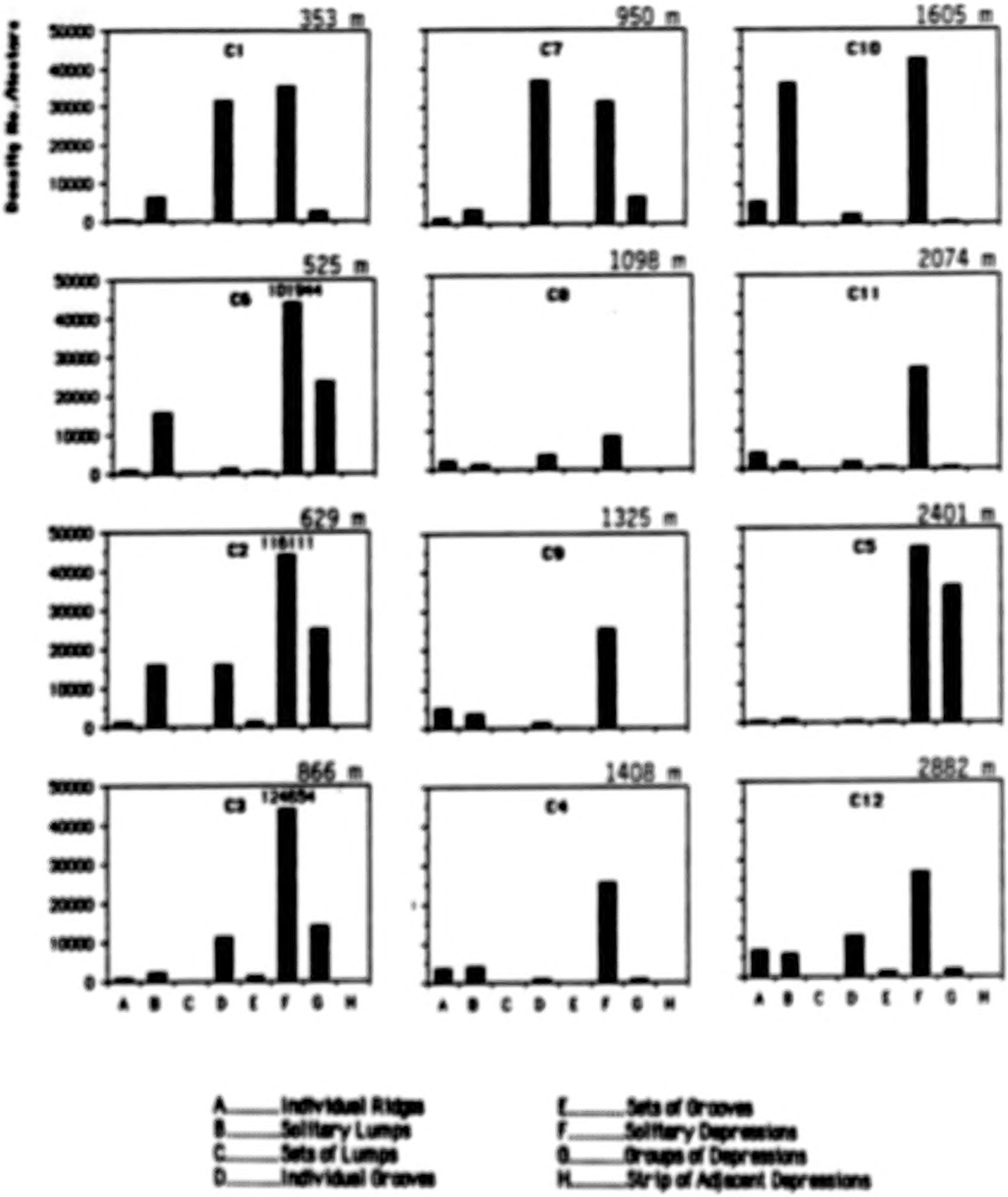
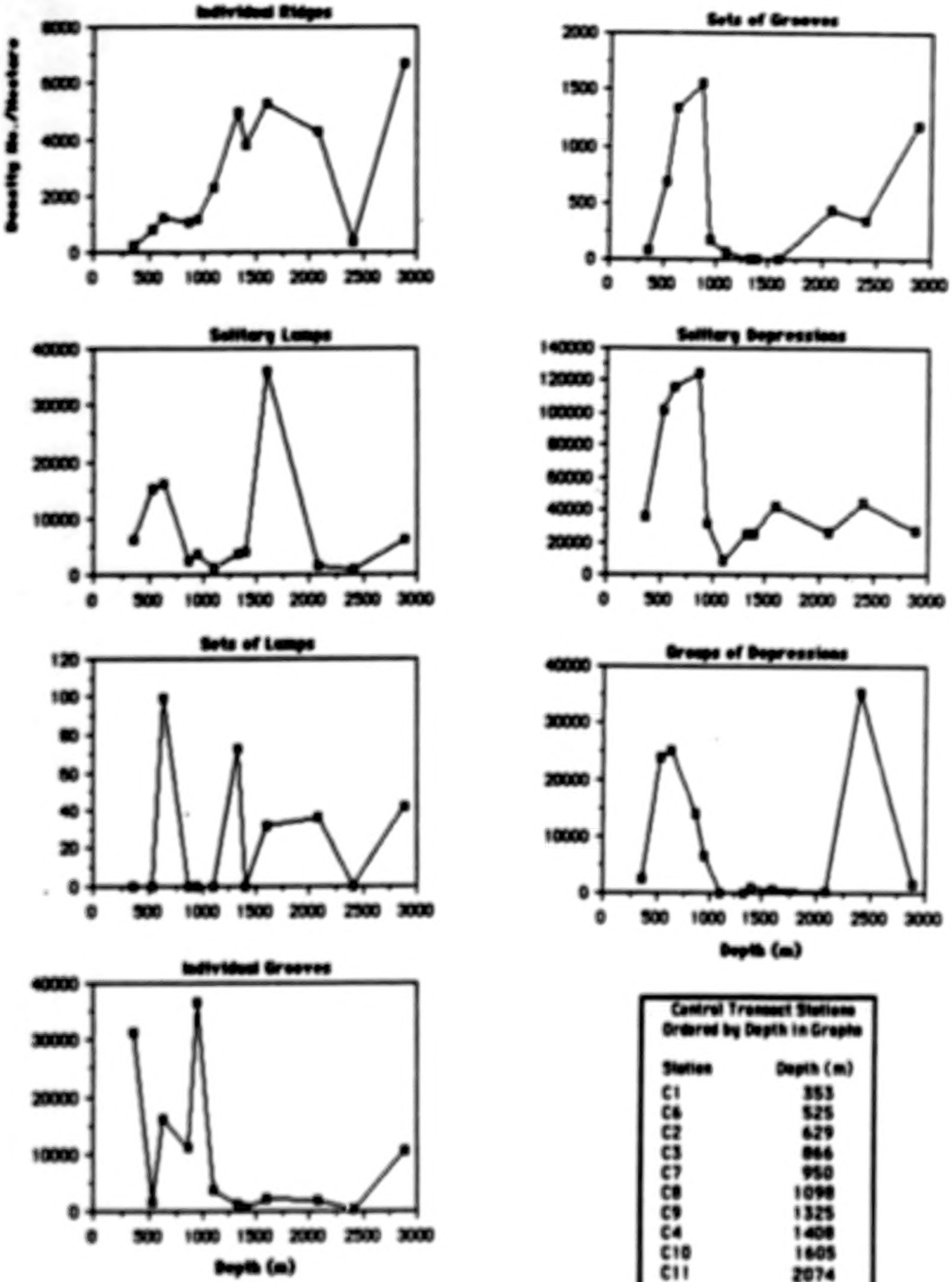


Figure 5-6. Major lebensspuren category densities by station, Cruise III.



Control Transect Stations Ordered by Depth in Graphs

Station	Depth (m)
C1	353
C6	525
C2	629
C3	866
C7	950
C8	1098
C9	1325
C4	1408
C10	1605
C11	2074
C5	2401
C12	2882

Figure 5-7. Cruise III density by depth (station) for separate major lebensspuren categories.

Two major categories in Figure 5-7, individual ridges and individual grooves, represented movement of animals across or just below the sediment's surface. The second ranked category in overall density, individual grooves, peaked at Station C7, primarily due to the numerous furrows left behind by vesicomyid clams found at this station (Appendix D1-4). Stations occurring between C8 at 1,098 m and C5 at 2401 m showed very low densities of individual grooves. Distribution of individual ridges was generally opposite to that of individual grooves. With increasing depth, individual groove density increased at Station C8 to relatively high levels throughout four of the deeper stations, C9, C4, C10 and C11. Station C5 showed very low densities of both individual grooves and ridges. Station C12 on the other hand, showed an increase in both lebensspuren types compared to the neighboring Station C5. An increase in density from Station C5 to C12 was also evident in two other categories shown in Figure 5-7, sets of grooves and solitary lumps.

The distribution pattern of solitary lumps was similar to the overall trend of total lebensspuren density with a peak at Station C2 and low densities at Station C1 and mid-depths below 700 m with the distinct exception of the very high density peak at Station C10 (1605 m). The unusual nature of bottom sediments and evidence of strong bottom currents discussed previously may have played a role in the presence of large numbers of solitary lumps at this station.

5.2 FAUNA

A total of 9147 benthic photographs were analyzed for biota representing a bottom area of 24,590 m^2 (Table 5-1). Sampling effort varied between project years; for Cruise II, 100 frames from each station were analyzed for biota and for Cruises III, IV, and V, 200 frames were analyzed from each station.

Faunal observations in benthic photographs were identified to the lowest possible taxon. As with any visual sampling technique, each taxonomic group possessed different attributes which contributed to variation in the accuracy of the identification. Assignment of taxonomic names was also a partially interpretive process, utilizing not only visual taxonomic keys, but also drawing upon other sources of information considered reliable for eliminating major gaps in identification quality. Additional sources of information used for making taxonomic assignments included subtle colors (visible only in live specimens), taxonomic lists of biota captured in trawls as the same station, and records of species ranges within the Gulf of Mexico or neighboring deep sea habitats.

These information sources were used very conservatively to avoid misidentifications; e.g., ignoring the possibility of a new species and forcing a particular observation into a specific previously recorded taxa. However, the utilization of additional information beyond taxonomic keys for identifications allowed relatively reliable, accurate processing of the data with greater resolution that would have been possible without these considerations.

As with all visual census techniques, lumping of unidentifiable taxa into taxonomic groups was unavoidable. In many cases, the uncertainties of visual identification occurs at the species level (e.g., many of the species of the macrourid fish Nezumia are visually indistinguishable) but there were also many groups which could not be identified visually beyond families, orders, and even classes or phylums (e.g., Porifera and Pogonophora).

5.2.1 NUMERICAL ABUNDANCE

A total of 20,755 individual animals were recorded from the 55 stations analyzed quantitatively (Cruises II-V). Due to the very low abundances of most taxa, and to allow comparisons between relative abundances, all data are presented as numbers of individuals per hectare or 10,000 m^2.

Appendices D2-2 to D2-5 detail all benthic photography biota densities for Cruises II-V to the lowest level of identification possible. In several of the groups such as Porifera or Ophiuroidea, the majority of the observations are listed as unidentified species numbers or letters. These taxa are believed to represent distinct species due to unique morphological characteristics or colors, etc., but could not be properly identified at this time.

Of the 245 total different biota taxa listed in Appendices D2-2 to D2-5, it is believed there are a minimum of 190 different species represented. Much of the overlap occurs when higher level taxa are assigned to a specific observation due to poor resolution or lack of identifiable characteristics. In many cases, the unidentified biota is assigned a genus, family or higher level name which may also be represented by species level identifications appearing in the same station's taxonomic list.

As a general overview of all megafauna observed in benthic photographs, Table 5-7 shows a summary of major biota group density over all 55 stations and four cruises using total abundance and total area surveyed of 24,950 m^2. Figure 5-8 illustrates the relative abundance of these major groups as a histogram. Six of the major groups appearing in Table 5-7 were deleted in this figure--bacteria, algae, plants, a single isopod and two unique groups, bivalves and tube worms which only occurred at isolated stations representing probable chemosynthetic communities.

Although these data represent a wide variety of stations ranging in depth from 300 to 3000 m, a general picture of the megafauna observable by a specific method of benthic photography on the continental slope of the Gulf of Mexico is illustrated. It is immediately apparent that very few megafaunal groups are represented by high densities. The group of animals with the highest density by far is the class Holothuroidea, which exhibited an overall density of 4645 individuals/ha. This value is over one half of the total density for all megafauna observed in benthic photography sampling.

The second ranked group shown in Table 5-7 is the bivalves which had an overall density of 1152/ha. However, this group was represented almost entirely at a single Station (C7) which had characteristics suggesting the presence of a chemosynthetic community as described in detail in the previous Annual Report (LGL and TAMU 1986).

Other major groups contributing a relatively large proportion of the overall density included Alcyonaria (primarily Pennatulacea or sea pens) with a density of 709/ha, decapod crustaceans with 612/ha, Porifera with a density of 462/ha and demersal fishes with an overall density of 198/ha.

Tables 5-8 through 5-11 present total biota densities from Cruises II-V summarized by major groups. These major groups (also used for megafauna and macrofauna data) vary in taxonomic level from classes in the case of the echinoderms, to phylums in cases such as Pogonophora or

Table 5-7. Total grouped densities, Cruises II-V.

Taxon	Total Abundance	Density (no./ha)
Schizomycetes	102	41.5
Phaeophyceae	145	59.0
Hydrocharitaceae	55	22.4
Porifera	1135	461.6
Alcyonaria	1744	709.2
Actiniaria	106	43.1
Scleractinia	10	4.1
Polychaeta	264	107.4
Gastropoda	40	16.3
Bivalvia	2832	1151.7
Scaphopoda	70	28.5
Cephalopoda	8	3.3
Isopoda	1	0.4
Decapoda	1505	612.0
Pogonophora/ Vestimentifera	223	90.7
Asteroidea	40	16.3
Ophiuroidea	425	172.8
Echinoidea	22	8.9
Holothuroidea	11,423	4645.4
Crinoidea	127	51.6
Ascidiacea	10	4.1
Demersal Fish	488	198.5
Totals	20,775	8448.6

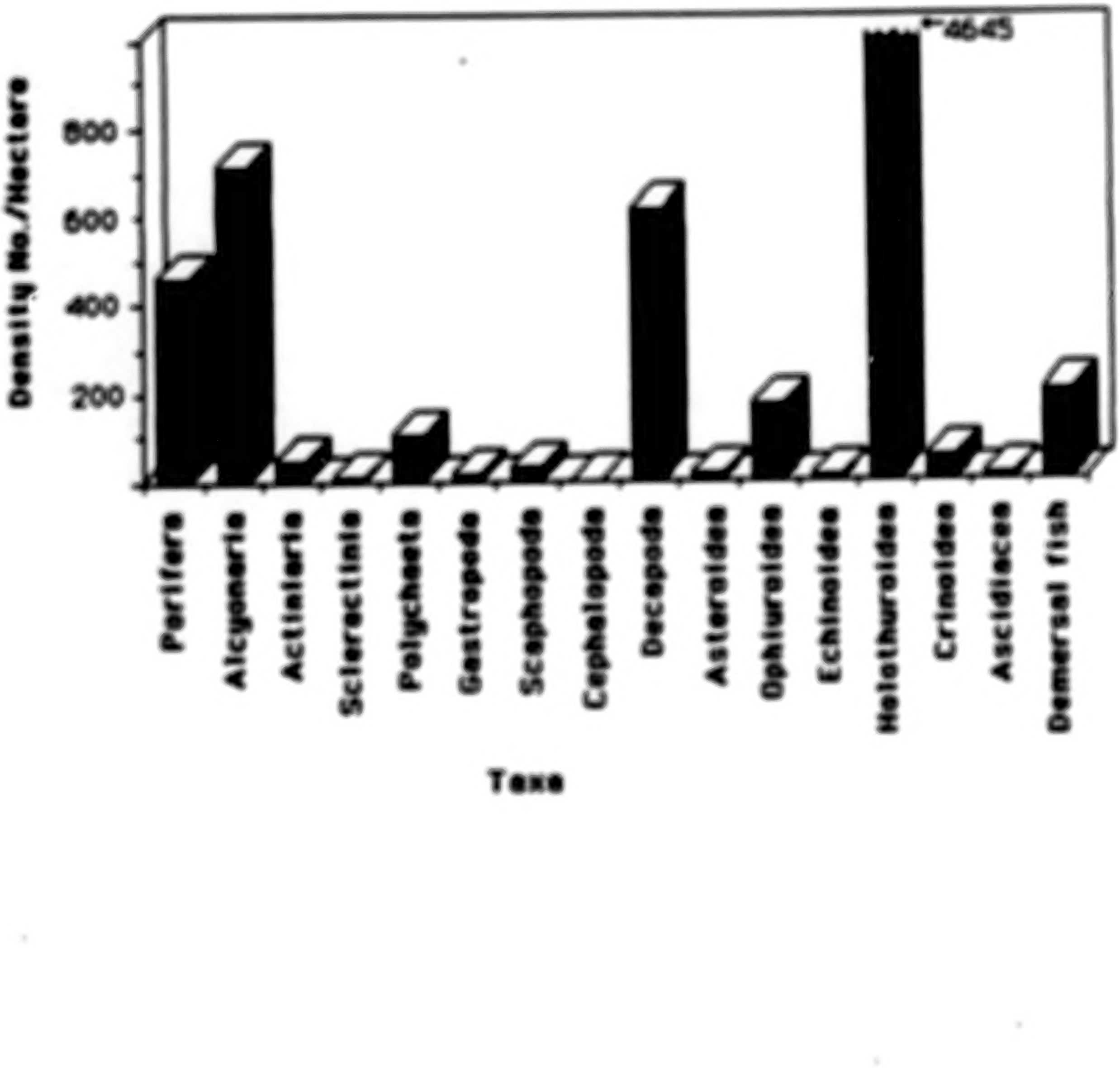


Figure 5-8. Total densities of major groups for all stations, Cruises II-V.

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Table 5-8. Benthic faunal density (No./ha): Cruise II Western.

Taxon	Station														
	V1	V2	V3	V4	V5	C1	C2	C3	C4	C5	E1	E2	E3	E4	E5
Hydrocharitaceae	49	0	0	0	69	105	0	28	0	0	0	0	0	0	42
Porifera	774	119	0	0	0	0	0	28	42	0	99	0	0	0	168
Alcyonaria	0	0	211	44	941	0	0	0	42	76	0	922	0	81	294
Actiniaria	290	0	0	0	0	0	85	0	42	76	66	76	0	0	0
Scleractinia	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0
Polychaeta	0	39	0	403	69	53	1372	375	510	0	0	0	65	0	168
Gastropoda	0	0	0	24,765	14,747	0	0	0	0	0	0	0	0	0	301,840
Scaphopoda	0	0	0	0	243	0	0	0	127	0	0	0	0	0	0
Cephalopoda	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0
Decapoda	920	199	317	582	34	1841	943	144	85	0	99	615	32	122	294
Pogonophora/ Vestimentifera	0	279	0	0	0	0	0	0	85	0	0	0	0	0	0
Asteroidea	0	0	0	0	0	53	85	28	0	0	0	0	32	0	0
Ophiuroidea	48	239	0	134	0	0	5662	57	0	38	0	307	32	0	42
Echinoidea	0	0	0	0	34	0	0	0	85	152	0	0	0	40	0
Holothuroidea	0	199	0	44	69	0	943	722	6215	76	0	76	0	0	168
Ascidiacea	0	0	0	0	0	0	171	0	42	0	0	0	0	0	0
Demersal Fish	290	239	0	0	0	684	171	202	0	0	99	230	197	50	0
Unknown	339	15,553	26,012	16,122	1847	316	25,224	3381	127	0	99	0	0	40	0
Total Biota (less pteropoda)	2371	1313	528	1207	1459	2631	9432	1584	7275	418	363	2226	358	323	1176

Table 5-9. Benthic faunal density (No./ha): Cruise III Central.

	Station											
Taxon	C1	C6	C2	C3	C7	C8	C9	C4	C10	C11	C5	C12
Schizomycetes	0	0	110	0	366	0	0	0	0	0	0	0
Phaeophyceae	19	15	0	396	18	232	186	53	175	145	33	49
Hydrocharitaceae	0	0	0	0	0	21	37	176	70	18	0	33
Porifera	97	265	94	20	0	739	149	16,514	0	0	0	
Alcyonaria	0	78	2612	20	952	147	186	212	788	802	183	249
Actiniaria	38	265	0	0	0	21	18	17	35	127	50	33
Scleractinia	0	0	15	0	0	0	0	0	0	0	0	0
Polychaeta	0	0	15	229	73	42	37	459	280	0	0	16
Gastropoda	174	0	8450	62,411	641	0	79,585	0	65,550	83,862	26,755	96,281
Bivalvia	0	0	0	41	51,566	42	37	0	227	0	0	0
Scaphopoda	0	0	0	0	0	42	93	35	175	200	0	116
Cephalopoda	0	0	0	0	0	0	0	0	0	0	0	16
Decapoda	194	3066	330	626	641	1035	579	212	350	255	83	99
Pogonophora/ Vestimentifera	0	0	94	0	91	0	0	17	0	0	0	0
Asteroidea	0	15	0	104	0	42	0	70	17	91	16	33
Ophiuroidea	0	78	424	208	238	126	130	0	0	0	50	16
Echinoidea	38	0	0	0	18	21	56	0	0	0	0	0
Holothuroidea	0	15	125	146	2877	4649	154,800	40,212	4014	127	250	16
Crinoidea	0	0	31	41	0	21	0	17	0	0	0	0
Demersal Fish	232	203	78	271	311	338	18	17	52	36	50	16
Artifacts	0	0	0	0	91	0	18	0	0	0	0	0
Consolidated Material	38	375	62	1253	439	1162	5173	3091	5627	5087	0	713
Unknown	58	0	15	104	421	21	0	106	140	72	0	16
Total Biota (less pteropoda)	792	4000	3928	2102	57,370	7518	156,344	41,638	22,697	1801	765	692

Table 5-10. Benthic faunal density (No./ha): Cruise IV Eastern.

Taxon	Station															
	E1B	E1A	E1	E1C	E2A	E2	E2E	E2B	E2D	E2C	E3	E3C	E3D	E3A	E3B	E5
Phaeophyceae	0	27	0	23	0	0	22	46	0	0	0	34	0	23	0	38
Hydrocharitaceae	0	27	0	207	0	0	45	0	0	0	46	17	20	47	0	248
Porifera	0	0	0	161	52	159	0	210	56	80	23	0	41	0	0	172
Alcyonaria	22	0	0	369	3778	1625	3095	2696	2029	4342	836	331	662	431	701	1129
Actiniaria	111	55	0	23	26	79	68	0	42	20	0	0	20	0	0	0
Scleractinia	0	0	0	0	0	0	0	0	0	0	0	34	0	0	0	0
Polychaeta	0	0	0	184	52	106	91	281	42	383	278	52	372	47	160	153
Gastropoda	0	0	0	0	26	0	0	0	0	0	0	0	20	23	20	0
Scaphopoda	0	0	0	0	0	26	0	0	0	0	0	0	0	0	0	153
Cephalopoda	0	0	0	0	0	0	0	0	56	0	46	0	0	0	20	0
Isopoda	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0
Decapoda	66	0	74	992	1433	2478	2246	1453	1000	2564	580	488	455	575	481	114
Pogonophora/ Vestimentifera	0	0	0	0	0	26	22	0	0	0	0	0	0	0	0	0
Asteroidea	22	0	0	23	52	0	22	0	14	0	23	0	0	0	0	0
Ophiuroidea	0	0	0	0	104	186	183	164	84	100	0	34	0	0	0	172
Echinoidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
Holothuroidea	0	0	0	0	26	26	22	0	42	40	23	0	0	0	0	95
Crinoidea	0	0	0	0	156	26	710	726	84	80	0	0	0	0	0	0
Ascidiacea	0	27	0	69	0	0	0	0	0	0	0	0	0	0	0	0
Demersal Fish	334	444	519	738	234	106	275	140	507	383	255	209	124	119	200	0
Unknown	0	0	0	0	0	186	0	0	0	0	0	0	0	23	0	19
Total Biota	555	580	593	2789	5939	4843	6823	5716	3956	7992	2110	1199	1714	1265	1582	2293

Table 5-11. Benthic fauna density (No./ha): Cruise V West-Central.

Taxon	Station WC5	WC1	WC7	WC8	WC4	WC2	WC6	WC3	WC9	W10	W12	W11
Schizomycetes	0	0	996	0	0	0	211	0	0	0	0	0
Phaeophyceae	36	21	33	54	71	34	0	66	106	15	267	483
Porifera	0	0	0	72	232	243	39	0	15	60	223	60
Alcyonaria	54	216	50	290	160	417	2264	243	196	165	193	140
Actiniaria	0	0	84	200	89	208	105	0	45	15	0	0
Scleractinia	0	0	33	18	0	0	39	0	0	0	0	0
Polychaeta	0	108	0	0	0	34	13	132	60	195	0	161
Gastropoda	91	64	0	0	0	0	0	22	15	45	14	0
Scaphopoda	109	0	0	0	0	0	0	0	0	15	104	0
Decapoda	127	454	135	72	357	974	370	819	560	540	506	926
Pogonophora/ Vestimentifera	0	0	3310	0	0	0	52	0	0	0	0	0
Asteroidea	36	0	16	0	0	34	0	44	0	15	0	20
Ophiuroidea	18	21	84	181	214	383	119	155	560	210	253	1731
Echinoidea	109	0	0	0	0	0	0	0	0	0	0	0
Holothuroidea	0	0	0	0	0	0	13	0	0	15	14	0
Crinoidea	0	0	0	0	0	0	463	132	15	0	0	0
Ascidiacea	0	0	0	54	0	0	0	0	0	0	0	0
Demersal Fish	438	216	219	236	428	87	198	88	181	195	89	483
Unknown	0	0	0	0	0	0	13	0	0	0	0	40
Total	1017	1100	4960	1177	1551	2414	3886	1701	1753	1485	1663	4004

Porifera. Total biota densities at the bottom of each column excludes the unknown category and non-biota categories of artifacts and consolidated material. Very high densities of what were believed to be fragments of pteropod shells were recorded at many stations. This record type was also subtracted from the total because of the probability that none of these records represented living organisms. Figure 5-9 illustrates these total biota densities in graphs of the four cruises including all 55 stations.

5.2.2 ABUNDANCE BY DEPTH

The following table summarizes densities for all transects together, by depth increments as used in other sections.

Depth	Mean Density (no./ha)
278- 500	1,575
500-1000	5,278
1000-2000	26,963
>2000	1,229

Faunal density was generally low at shallow stations and was lowest in water deeper than 2000 m. The depth range of 1000-2000 m showed the highest mean density by more than a factor of five compared to the next lower depth increment. This high density was due to the very high numbers of the holothuroid Peniagone sp. encountered at four mid-depth stations sampled during Cruise III; Stations C8, C9, C4, and C10. When the density contribution of this solitary taxa is removed from the total for the 1000-2000 m depth increment, the overall density is reduced to 4365/ha. The contribution of this particular genus is also seen in comparison of densities by transect. Peniagone sp. was not collected in the trawls.

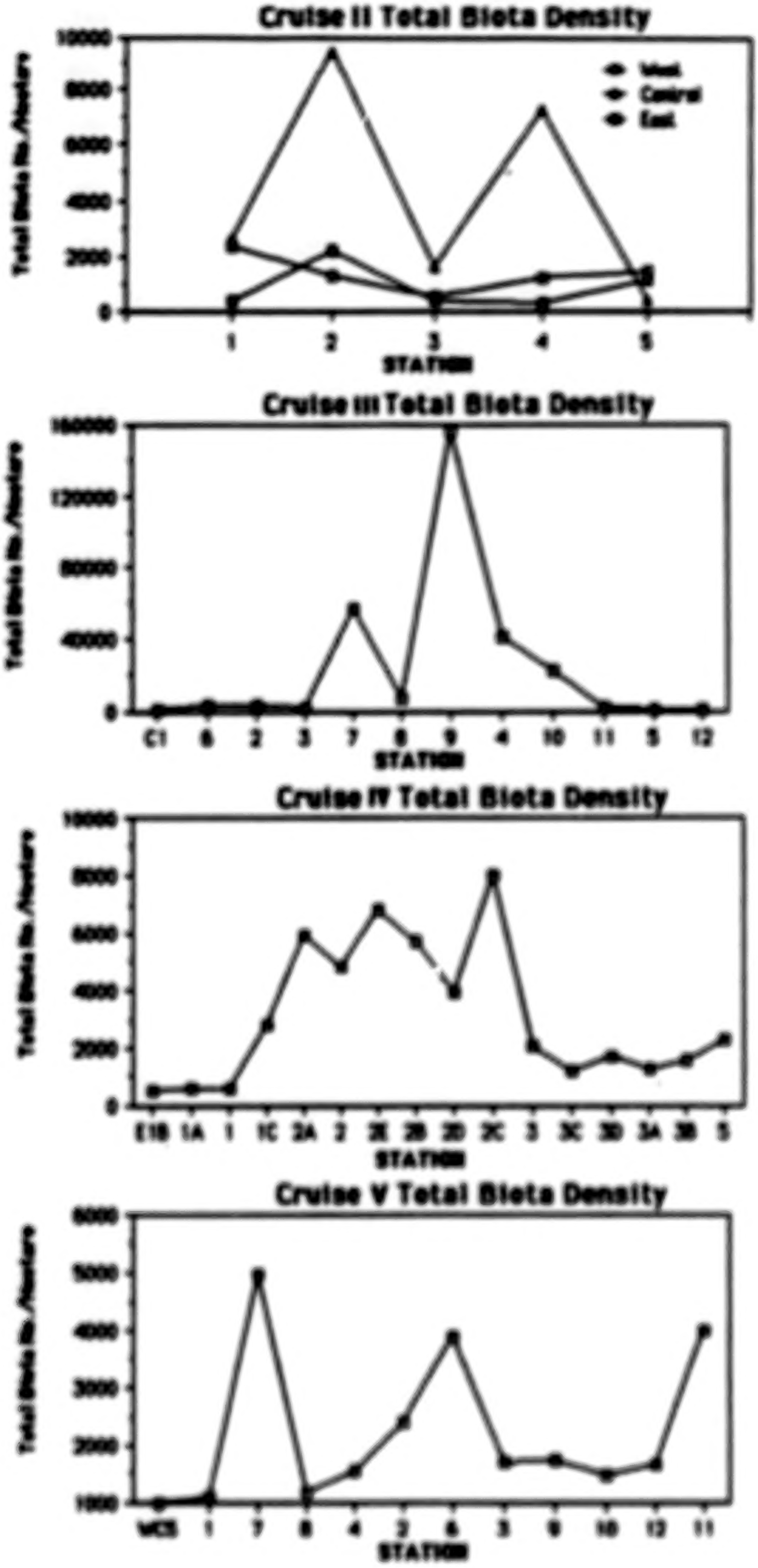

Figure 5-9. Total biota density from benthic photography by station, Cruises II-V.

5.2.3 ABUNDANCE BY TRANSECT

The following table lists mean total densities of all fauna by transect:

Cruise	Transect	Mean Density (no./ha)
2	Western	1,365
	Central	4,268
	Eastern	889
3	Central	24,970
4	Eastern	3,122
5	West-Central	2,226

Over all mean densities on the Central Transects were consistently higher than at other transects. Again, the holothuroid Peniagone sp. was the most significant contribution to these density values. During Cruise 2, this taxa was encountered at two stations, C3 and C4. At Station C4, the contribution of Peniagone sp. density to the total biota density for the entire station was a very significant 85% as illustrated in Figure 5-9. The high station density at Station C2 was due primarily to an unidentified ophiuroid taxa represented by a relatively high density of 5662/ha. The very high transect density of 24,970 individuals/ha on the Central Transect during Cruise 3 was due almost entirely from the extremely high abundance of the Peniagone sp. holothuroid. Five stations, C7, C8, C9, C4, and C10 exhibited high densities of Peniagone sp. resulting in the density peaks shown in Figure 5-9.

The Eastern and West-Central Transects sampled during Cruises IV and V were moderate in overall biota density. The Eastern Transect from Cruise IV, with a mean density of 3122 individuals/ha, showed higher densities through the six mid-depth stations between Stations E2A and E2C representing depths between 624-667 m illustrated in order of depth in Figure 5-9. Two major taxa contributed to these higher biota densities; several pennatulacea taxa and a number of decapod crustacean taxa (Appendix D2-4). Both the shallower stations in the 338-360 m depth range and the deeper stations between 809 and 2,890 m were all lower in mean biota density.

The West-Central Transect during Cruise V had mean biota density of 2,226 individuals/ha. Station WC7, representing the highest density of the transect is unique. A single taxa group, Pogonophora/Vestimentifera, contributed a density of 3309/ha to the total for the station total of 4960/ha. The bulk of the records (2905/ha) making up the total Pogonophora/Vestimentifera density were recorded as vestimentiferans considered to be chemosynthetic (LGL and TAMU 1986).

5.2.4 DENSITY DIFFERENCES WITHIN TRANSECTS

Two seasonal comparisons were possible in benthic photography results. The Central Transect was sampled both during Cruise II in March 1984, and during Cruise III in November 1984. Five of the 12 total Central Transect stations were sampled during both cruises; Stations C1, C2, C3, C4, and C5. Several stations on the Eastern Transect were also sampled on two separate cruises. Stations E1, E2, E3, and E5 were sampled both during Cruise II in March 1984 and also during Cruise IV in August of 1985. Mean densities for these stations sampled on multiple occasions are shown in Table 5-12.

On the Central Transect, mean density in spring 1984 (Cruise III) was more than double that of winter 1984 (Cruise II) (9845/ha and 4268/ha, respectively). A similar decrease in total density from Cruise II sampling was found on the Eastern Transect stations shared between Cruises II and IV. The mean total biota density of the four replicated Eastern Transect stations was more than double in summer 1985 samples (Cruise IV) compared to winter 1984 (Cruise II) (2460/ha and 1031/ha, respectively). The variation in sampling effort between Cruise II (100 frames/station) and both Cruises III and IV (200 frames/station) may be the cause of these transect variations.

5.2.5 SEASONAL DIFFERENCES IN NUMBER OF TAXA

Numbers of recognizable taxa in benthic photographs were quite low in comparison to other sampling techniques. Use of these data for

Table 5-12. Total biota densities for all stations sampled on multiple cruises.

Station	Cruise II	Cruise III	Station	Cruise II	Cruise IV
C1	2631	792	E1	363	593
C2	9432	3928	E2	2226	4843
C3	1584	2102	E3	358	2110
C4	7275	41,638	E5	1176	2293
C5	418	765			
Mean Density	4268	9845		1031	2460

Table 5-13. Numbers of unique taxa for all stations and transect totals, Cruises II-V.

Cruise II		Cruise III		Cruise IV		Cruise V	
Station	No. Taxa	Station	No. Taxa	Station	No. Taxa	Station	No. Taxa
W1	14	C1	14	E1B	11	WC5	11
W2	11	C6	22	E1A	11	WC1	19
W3	3	C2	20	E1	6	WC7	23
W4	6	C3	22	E1C	17	WC8	22
W5	8	C7	28	E2A	30	WC4	26
Total	35	C8	37	E2	22	EC2	21
C1	14	C9	23	E2E	31	WC6	34
C2	12	C4	24	E2B	29	WC3	20
C3	15	C10	20	E2D	32	WC9	28
C4	12	C11	15	E2C	32	WC10	33
C5	5	C5	15	E3	19	WC12	16
Total	41	C12	20	E3C	21	WC11	22
E1	5	Total	123	E3D	21	Total	118
E2	10			E3A	14		
E3	8			E3B	18		
E4	5			E5	26		
E5	9			Total	123		
Total	29						

calculation of diversity indicies would be of little value due to the wide variety of species groups that represented more than a single species. Total numbers of taxa recorded in benthic photographs by cruise and station are shown in Table 5-13.

The most noticeable contrast is evident in comparison between numbers of taxa recorded from Cruise II (March) compared to the other three cruises. Numbers of separate taxa on the three transects of Cruise II ranged between 29 on the Eastern Transect to 41 on the Central Transect. Numbers of taxa represented on the other three cruises were approximately three times as high, ranging between 118 on Cruise V and 123 taxa from both Cruises III and IV. The most likely explanation for these differences is the sampling intensity--the number of frames analyzed for biota during Cruises III, IV, and V was double that of Cruise II. There may also be seasonal or other temporal effects involved but this possible cause of variation cannot be separated from possible effects of variable sampling intensity. The effects of unequal sampling effort upon numbers of taxa was also evident in the macrofauna data.

The number of different taxa recorded in benthic photographs were averaged by depth increments over all transects and all four cruises resulting in the following distribution:

Depth Range	No. of Taxa
278- 500	15
500-1000	26
1000-2000	18
>2000	14

Total number of taxa by depth increment matched the pattern shown by macrofauna with the highest number occurring in the intermediate depths and lower numbers at the shallower and deeper stations.

5.2.6 SIZE MEASUREMENTS FROM BENTHIC PHOTOGRAPHS

By the use of digitizing procedures described in Section 2.3.1.4, objects appearing in benthic photographs and located on a level bottom surface could be measured for length or surface area. A total of 16,049 length measurements (Appendix D3-2) and 328 area measurements (Appendix D3-3) were obtained. Table 5-9 shows several representative examples of length measurements. Appendix D3-1 summarizes biota length measurements from all 55 stations for each taxa.

The principal utility of this technique is most evident when taxa are measured that are rare or non-existent in trawl samples. The case of the extremely abundant holothuroid, Peniagone sp. is an exceptional example. This was the most abundant taxon in all 55 stations sampled by benthic photography with a peak density of 154,669 individuals/ha at Station C9 during Cruise III, but was not recorded from a single trawl sample. A total of 11,326 were recorded and 10,581 of these were measured (Table 5-14).

5.2.7 SELECTED SPECIES ACCOUNTS

Several taxa were represented in sufficient numbers and are selected for further description in this Annual Report. The holothuroid Peniagone sp. (identified from photographs by Dr. R. Carney) was the most numerous organism recorded in all of the 9147 analyzed photographs. It was observed at six different stations on the Central Transect during Cruises II and III over a relatively narrow depth range, as illustrated in Figure 5-10. The very high peak density of 154,669 individuals/ha occurred at Station C9 at a depth of 1325 m. The very narrow depth and station distribution of this species and their close proximity to chemosynthetic communities in the same area suggests a possible association.

The length distribution of all observed Peniagone sp. ranged from 1.0-7.4 cm with a mean of 2.96 cm (Appendix D3-1). Figure 5-10 shows the length frequency distribution for the 10,581 individuals that were measured.

Bembrops gobioides was one of the more numerous fishes recorded by benthic photography. A total of 47 individuals occurred at 12 stations (Appendix D3-1). Although it was relatively low in abundance compared to the total of 367 specimens collected by trawling, the total density was significantly higher than that estimated from trawling due to the smaller area photographed.

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Table 5-14. Sample of length measurements from benthic photography.

Taxa	Abundance	Number of Stations	Number Measured	Mean Length (cm)	Minimum Length (cm)	Maximum Length (cm)
Thalassia sp.	49	17	49	13.9	4.9	29.3
Hyalinoecia tubicola	69	12	68	20.7	3.9	51.7
Glyphocrangon sp.	51	21	46	3.1	0.9	5.3
Munida valida	42	6	16	3.4	1.8	4.5
Natantia	1268	47	810	2.7	0.5	20.0
Ophiuroidea sp. 6	160	6	159	6.3	3.6	17.4
Peniagone sp.	11,326	9	10,581	3.0	1.0	7.4
Synaphobranchus sp.	32	14	16	45.1	12.0	60.6
Bembrops gobioides	47	12	45	20.2	6.6	34.3
Chlorophthalmus agassizi	49	10	47	10.5	4.3	18.4

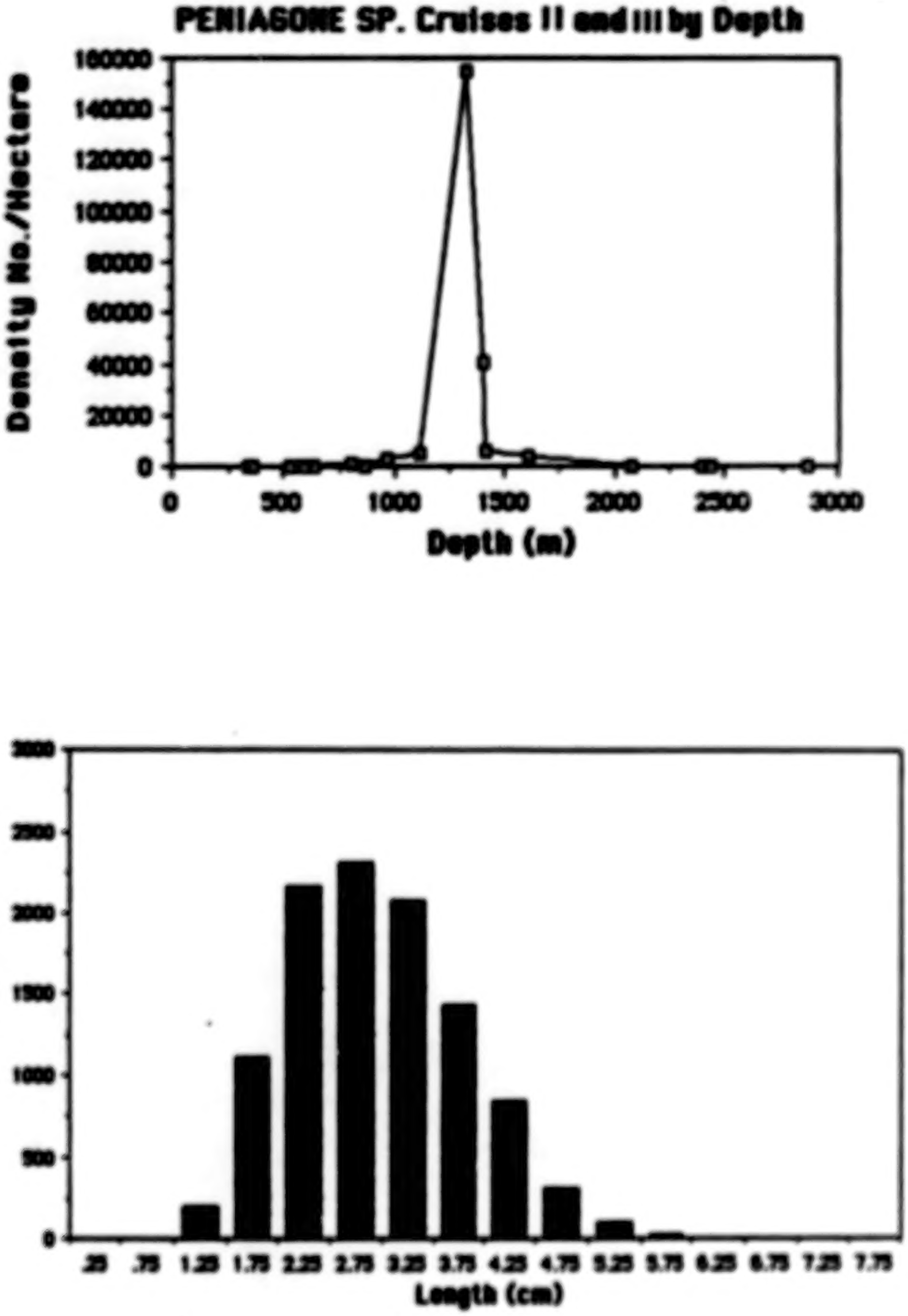

Figure 5-10. Distribution by depth and length frequency distribution of Peniagone sp., Cruises II and III.

The distribution by depth and length frequency distribution for *B. gobioides* are shown in Figure 5-11. This fish occurred only at shallow stations between 274 and 579 m. Length measurements ranged from 6.6 to 34.3 cm with a mean of 20.2 cm. The mean length found from benthic photography sampling was slightly higher than that determined from trawl samples (202 mm and 190 mm, respectively) which is probably caused by measurement of total lengths in benthic photographs as opposed to fork length in trawl specimens. There appears to be at least two growth cohorts shown in Figure 5-11, although the abundance of the smaller individuals producing the first mode was very small. Interestingly, additional size cohorts were also seen in the trawl collections.

Chlorophthalmus agassizi was another fish well represented in benthic photography samples. A total of 49 individuals were recorded from 10 different stations. As shown in Figure 5-12, this fish was also represented only at shallow stations of the continental slope between 355 and 766 m depths.

A total of 47 individuals were measured with a mean length of 10.5 cm ranging from a minimum of 4.3 cm to a maximum of 18.3 cm (Appendix D3-1). Figure 5-12 presents the length frequency distribution for these total length measurements. Similar to the case of *B. gobioides* above, this species appears to be represented by several growth cohorts which were also evident in trawl collections. The mean length for trawl samples was 9.5 cm compared to 10.5 cm for benthic photography samples, the difference due at least in part to the measurement of total length in photographs as opposed to fork length of trawl specimens.

A total of 37 *Synaphobranchus* sp. were observed from 12 stations from all cruise samples. All of these observations were most probably *S. oregoni* and were inadvertently divided between the species classification and the unknown species listing in the appendices. The mean length for these observations was 45.1 cm ranging between 24.5 and 60.6 cm. In the case of this taxa, benthic photography measurements were also larger than the trawl mean of 41.5 cm, but this difference cannot be attributed to the measurement of fork lengths for this eel species.

Distribution by depth is presented in Figure 5-13. *Synaphobranchus* sp. were seen primarily throughout mid-depths between 604 and 1246 m.

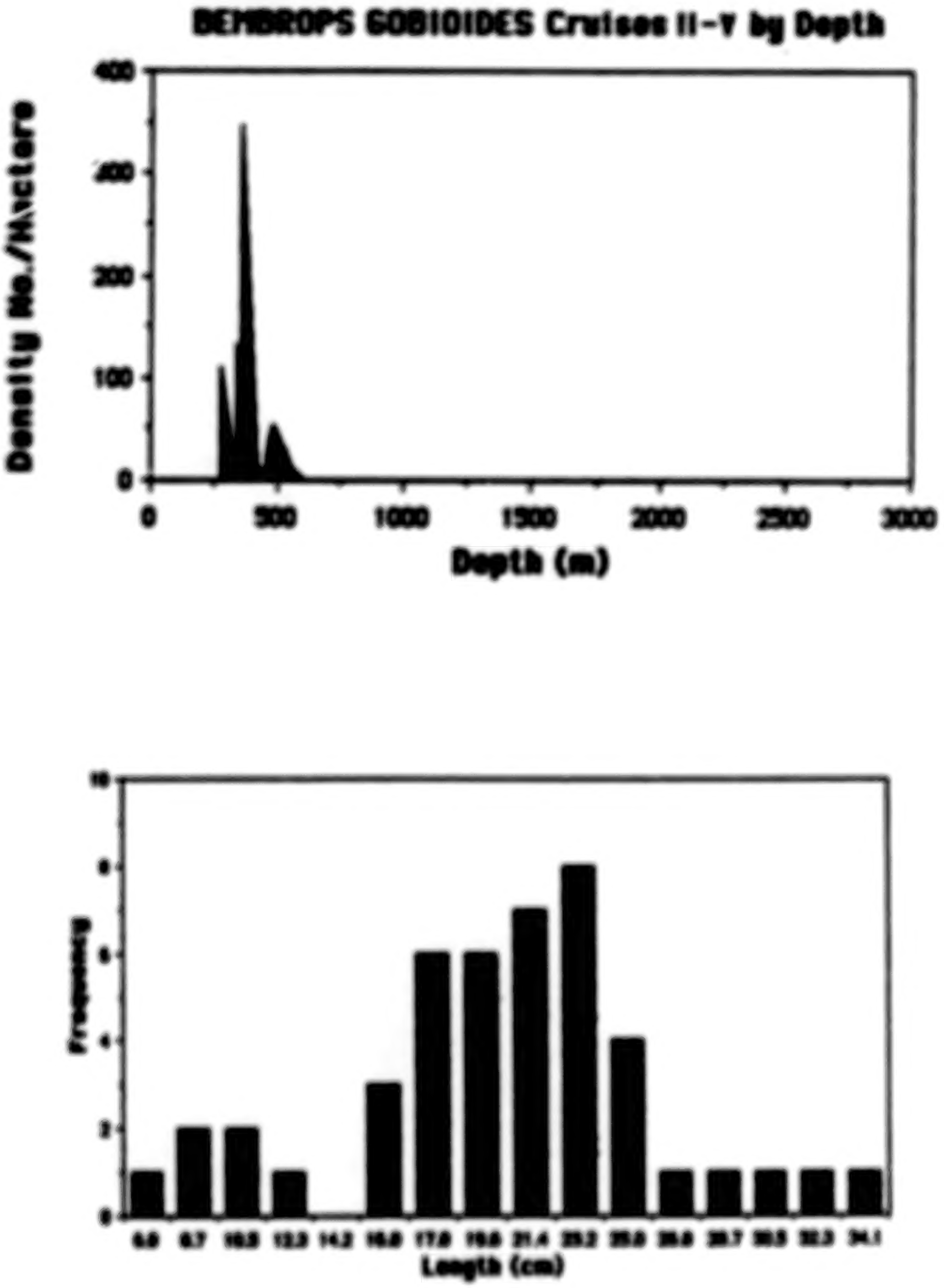

Figure 5-11. Distribution by depth and length frequency distribution of *Bembrops gobioides*, Cruises II-V.

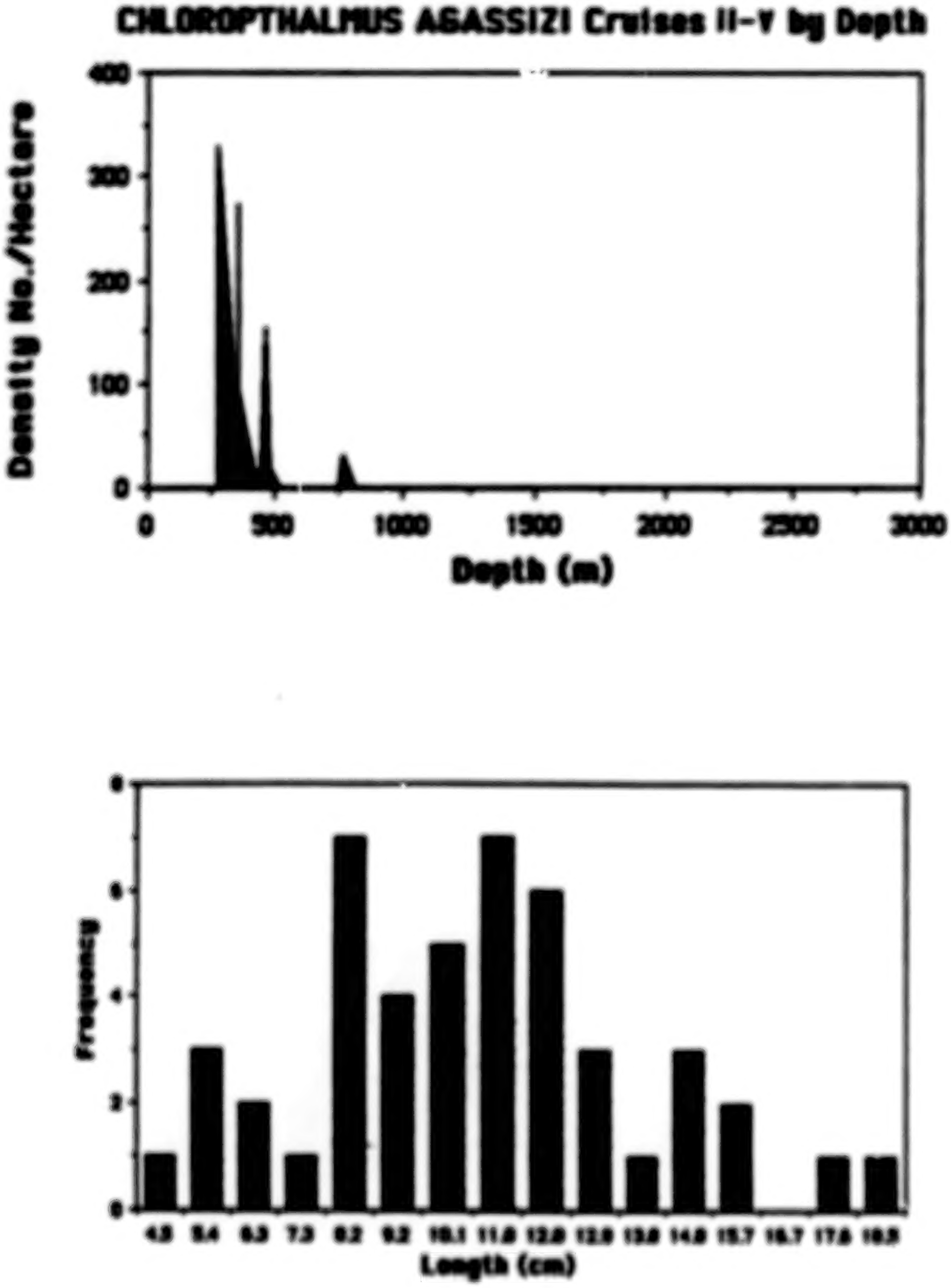

Figure 5-12. Distribution by depth and length frequency distribution of *Chloropthalmus agassizi*, Cruises II-V.

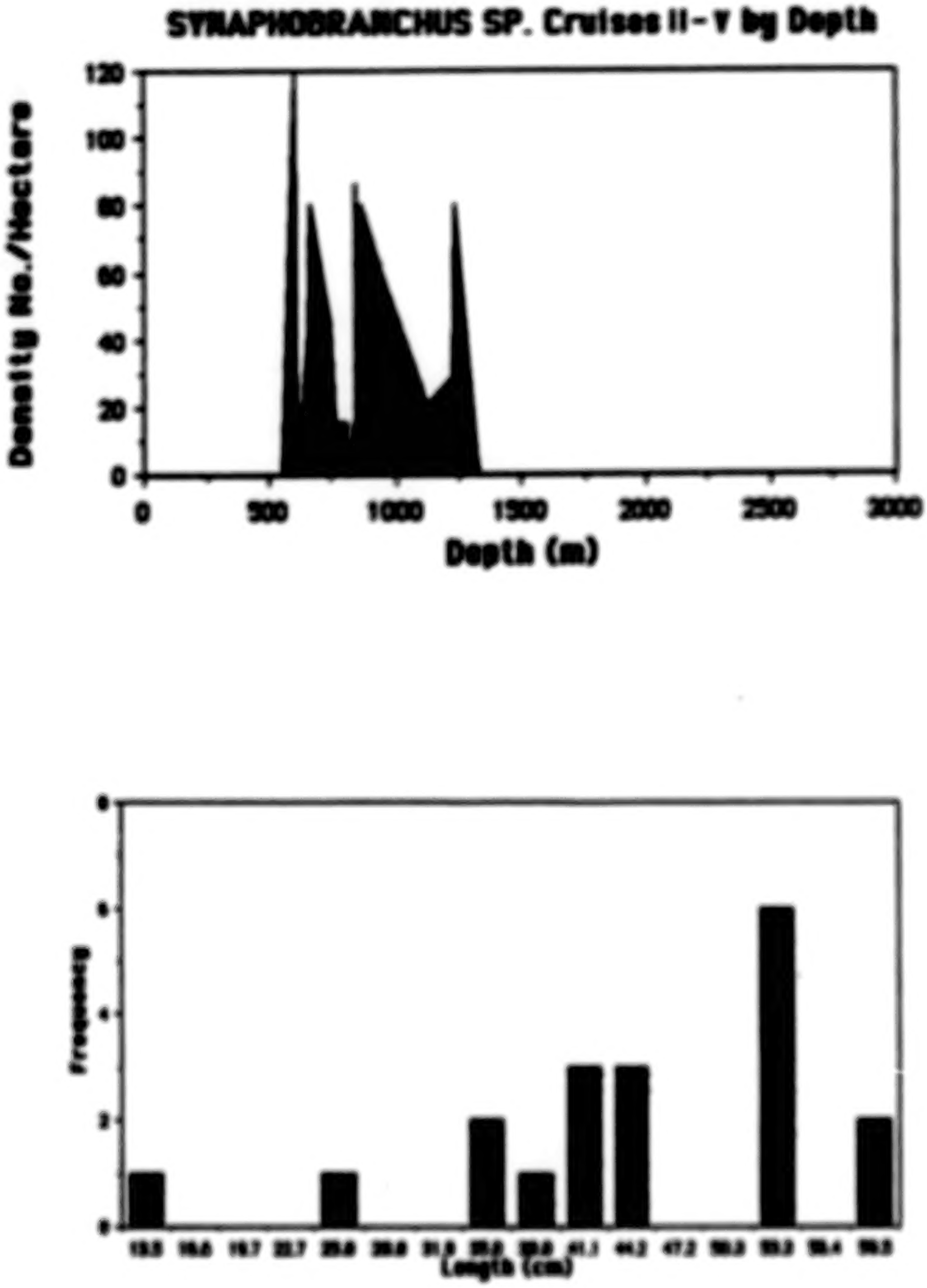

Figure 5-13. Distribution by depth and length frequency distribution of Synaphobranchus sp., Cruises II-V.

The density of the galatheid crab Munida valida is illustrated in Figure 5-14. This galatheid was only recorded during Cruise IV and was represented only at the mid-depth stations between 629 and 662 m. Only 16 measurements were possible from the 42 total observations resulting in a mean carapace length of 3.4 cm ranging from a minimum of 1.8 cm to a maximum of 4.5 cm.

5.2.8 COMPARISONS OF BENTHIC PHOTOGRAPHY AND TRAWL DENSITIES

Tables 5-15 through 5-17 present overall megafauna group densities derived from trawling and benthic photography samples from Cruises III, IV, and V, respectively. Cruise II density data were not included in these comparisons because of the fewer number of analyzed frames (100 compared to 200 for the subsequent three cruises). Calculation of bottom areas sampled by trawling (necessary for density calculations) took into account the expected mouth opening of the trawl when fishing normally, and length of the trawled area derived from the time the trawl spent on the bottom and the logged speed of the vessel.

Figures 5-15, 5-16 and 5-17 present these data in graphs for selected megafauna groups (decapod crustaceans, combined asteroids and ophiuroids, and demersal fishes), and total megafauna (all groups combined). The major groups were chosen for comparison because of the similar likelihood that both trawling and benthic photography would obtain representative samples. Some other groups would be expected to be sampled more efficiently by benthic photography, e.g., sea pens (Alcyonaria) or other biota groups attached to, or buried below the surface of the substrate. Yet other groups would be expected to be sampled more efficiently by trawling in comparison to a visual technique. These groups would include small individuals such as barnacles, solitary corals and other taxa not easily observed in photographs.

The overall results indicated that with very few exceptions, megafauna densities obtained from benthic photography greatly exceeded those obtained from trawling. During Cruise III, the density differences between the two sampling methodologies was the most pronounced with variations in some cases being more than four orders of magnitude (Station C9, Table 5-15). The dramatic differences between benthic photography and

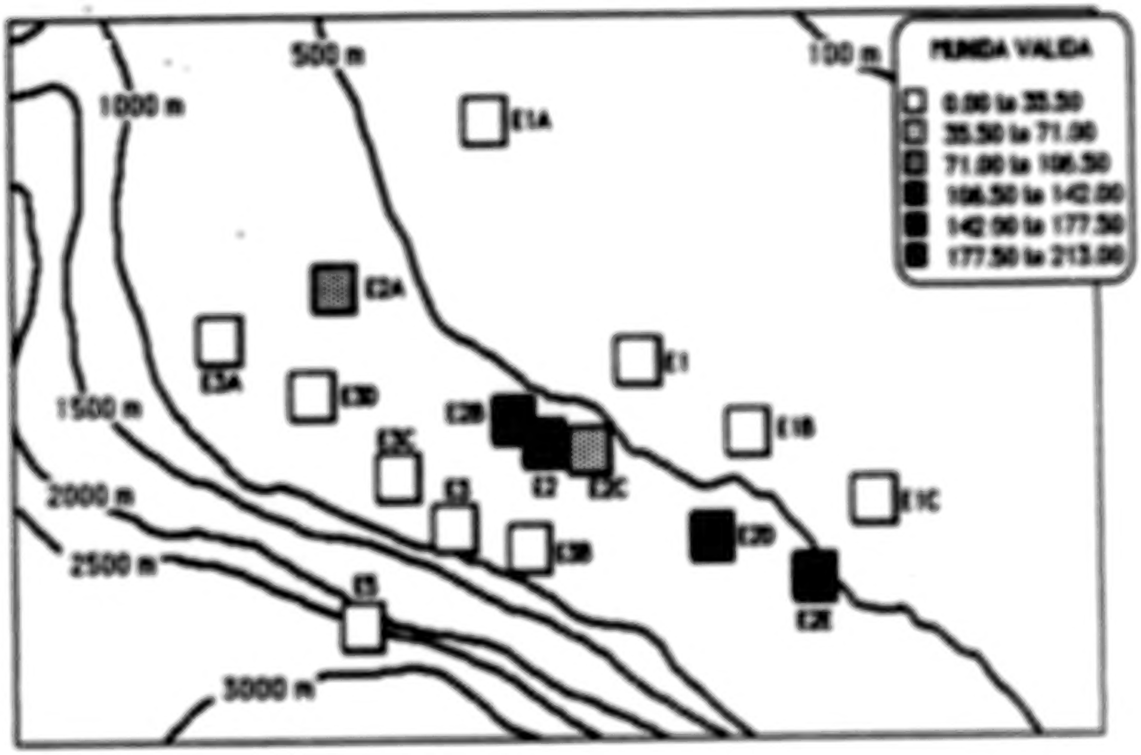

Figure 5-14. Station distribution of density for *Munida valida*, Cruise IV.

Table 5-15. Total megafauna density (no./hectare) from trawling and benthic photography: Cruise III.

Taxa		C1	C6	C2	C3	C7	C8	C9	C4	C10	C11	C5	C12
PORIFERA	Trawl	0	0	0	1	1	5	3	2	0	1	5	*
	Photography	98	284	54	20	0	730	147	140	16,514	0	46	0
ALCYONARIA	Trawl	0	0	0	0	0	0	0	0	0	1	14	*
	Photography	0	76	2811	20	651	147	186	212	768	602	162	247
ACTINIARIA	Trawl	4	1	0	3	4	0	0	0	2	15	5	*
	Photography	38	285	0	0	0	21	18	17	35	127	50	33
DECAPODA	Trawl	91	186	100	34	62	115	0	16	2	7	10	*
	Photography	192	3085	328	625	640	1024	577	210	250	254	67	98
BIVALVIA	Trawl	0	1	8	0	1	9	2	10	0	0	1	*
	Photography	0	0	0	41	51,565	42	37	0	227	0	0	0
OPHIUROIDEA	Trawl	1	8	162	3	1	4	0	2	0	5	30	*
	Photography	0	77	423	208	237	126	129	0	0	0	49	16
ECHINOIDEA	Trawl	0	0	0	0	0	2	0	1	1	0	0	*
	Photography	38	0	0	0	19	21	56	0	0	0	0	0
ASTEROIDEA	Trawl	0	2	2	25	7	9	6	18	3	16	12	*
	Photography	0	15	0	103	0	42	0	70	17	90	16	33
HOLOTHUROIDEA	Trawl	0	19	0	14	10	2	0	2	0	10	34	*
	Photography	0	15	125	145	2877	4848	154,799	40,211	4014	127	249	16
CRINOIDEA	Trawl	0	0	0	0	0	1	0	0	0	0	0	*
	Photography	0	0	31	41	0	21	0	17	0	0	0	0
OTHER INVERTEBRATE	Trawl	4	3	2	282	123	12	1	8	55	7	8	*
	Photography	174	0	124	229	382	84	148	511	454	200	0	148
DEMERSAL FISH	Trawl	54	119	35	44	34	50	0	4	5	4	4	*
	Photography	231	200	76	287	307	338	18	17	52	36	50	16
TOTALS	Trawl	154	342	336	406	243	213	12	61	68	66	124	*
	Photography	793	3976	3812	1886	56,977	7262	156,115	41,408	22,415	1636	728	605

* Station C12 Not Trawled

Table 5-16. Total megafauna density (no./hectare) from trawling and benthic photography: Cruise IV.

Taxa		E1B	E1A	E1	E1C	E2A	E2	E2E	E2B	E2D	E2C	E3	E3C	E3D	E3A	E3B	E5
PORIFERA	Trawl	1	2	4	2	10	14	5	21	18	10	2	2	1	2	4	*
	Photography	0	0	0	161	52	159	0	210	58	80	23	0	40	0	0	171
ALCYONARIA	Trawl	0	5	2	0	59	101	13	66	183	51	9	6	3	3	11	*
	Photography	22	0	0	359	3777	1523	3061	2661	2027	4339	635	329	661	429	701	1129
ACTINIARIA	Trawl	1	7	2	20	0	0	0	0	7	0	0	1	0	0	0	*
	Photography	111	54	0	23	26	79	67	0	42	20	0	0	20	0	0	0
DECAPODA	Trawl	152	167	294	329	329	309	264	272	638	384	47	88	63	101	56	*
	Photography	66	0	74	992	1432	2479	2243	1451	999	2582	580	486	453	574	481	114
BIVALVIA	Trawl	4	0	1	4	8	0	2	26	18	3	6	9	12	10	2	*
	Photography	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OPHIUROIDEA	Trawl	6	4	4	4	21	35	29	41	36	40	2	4	7	6	5	*
	Photography	0	0	0	0	104	185	182	162	84	100	0	34	0	0	0	171
ECHINOIDEA	Trawl	1	0	0	0	1	6	3	1	4	5	0	0	0		0	*
	Photography	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
ASTEROIDEA	Trawl	1	7	0	1	41	20	10	28	18	12	5	10	12	22	2	*
	Photography	22	0	0	23	52	0	22	0	14	7	23	0	0	0	0	0
HOLOTHUROIDEA	Trawl	0	0	0	2	4	0	1	0	2	1	5	6	11	11	5	*
	Photography	0	0	0	0	26	26	22	0	42	40	23	0	0	0	0	95
CRINOIDEA	Trawl	0	1	1	0	7	18	7	22	22	14	3	1	1	0	2	*
	Photography	0	0	0	0	156	26	710	725	84	60	0	0	0	0	0	0
OTHER INVERTEBRATE	Trawl	19	13	34	28	28	27	16	39	63	28	9	15	15	10	15	*
	Photography	0	27	0	253	78	158	135	280	98	382	324	85	391	89	200	305
DEMERSAL FISH	Trawl	52	126	191	88	85	42	21	44	57	44	23	40	34	87	27	*
	Photography	331	441	518	737	234	105	268	138	526	380	253	206	120	116	200	0
TOTALS	Trawl	237	332	533	478	593	572	371	560	1100	592	110	194	159	252	129	*
	Photography	552	522	592	2558	5927	4839	6740	5657	3952	7983	2081	1140	1685	1186	1562	2003

* Station E5 Not Trawled

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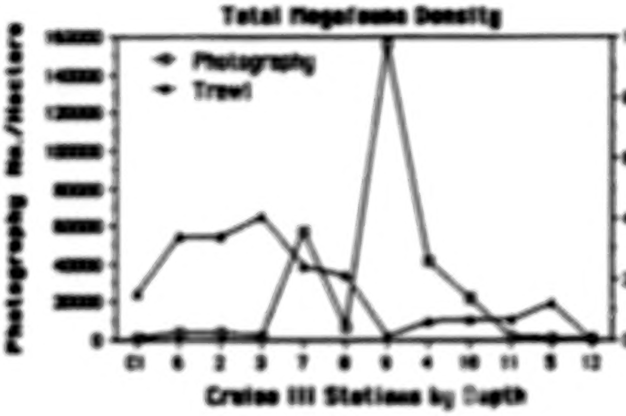
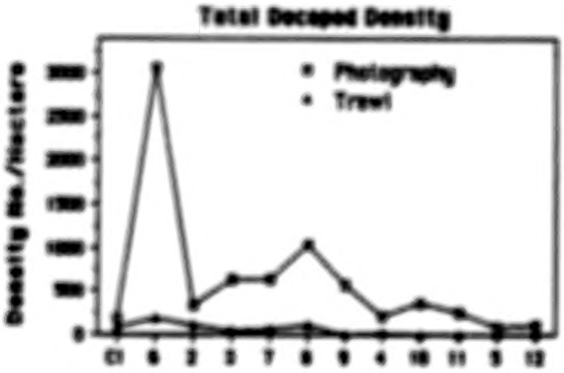
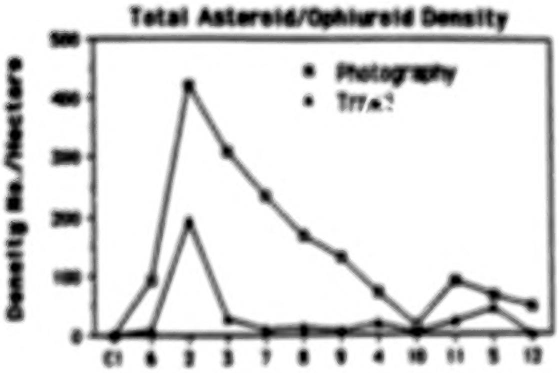
Table 5-17. Total megafauna density (no./hectare) from trawling and benthic photography: Cruise V.

Taxa		VC5	VC1	VC7	VC8	VC4	VC2	VC6	VC3	VC9	V10	V12	V11
PORIFERA	Trawl	0	4	2	3	5	0	16	20	2	0	611	18
	Photography	0	0	0	72	230	243	39	0	15	60	221	60
ALCYONARIA	Trawl	0	2	7	1	23	1	9	0	0	0	1	1
	Photography	54	215	49	290	157	416	2253	243	195	165	193	140
ACTINIARIA	Trawl	19	44	25	0	27	17	3	0	10	0	0	26
	Photography	0	0	83	199	88	208	105	0	45	15	0	0
DECAPODA	Trawl	100	252	174	484	153	43	146	97	162	25	122	496
	Photography	127	452	134	72	354	973	369	819	558	540	505	925
BIVALVIA	Trawl	29	3	4	2	1	11	11	24	5	3	84	19
	Photography	0	0	0	0	0	0	0	0	0	0	0	0
OPHIUROIDEA	Trawl	2	7	118	149	62	20	47	47	69	8	22	46
	Photography	18	21	83	181	213	382	118	154	560	210	253	1731
ECHINOIDEA	Trawl	0	0	0	0	0	0	3	10	1	0	6	6
	Photography	109	0	0	0	0	0	0	0	0	0	0	0
ASTEROIDEA	Trawl	1	9	4	2	0	3	9	28	13	2	5	1
	Photography	36	0	16	0	0	34	0	44	0	15	0	20
HOLOTHUROIDEA	Trawl	0	3	2	4	2	8	1	1	1	0	6	4
	Photography	0	0	0	0	0	0	13	0	0	15	14	0
CRINOIDEA	Trawl	0	0	0	1	3	2	7	6	0	1	1	0
	Photography	0	0	0	0	0	0	462	132	15	0	0	0
OTHER INVERTEBRATE	Trawl	9	23	115	19	15	5	101	26	27	0	31	9
	Photography	200	170	3342	72	0	34	104	154	75	255	118	160
DEMERSAL FISH	Trawl	96	78	145	144	54	38	51	42	70	14	24	106
	Photography	437	213	213	234	422	85	195	88	180	195	85	480
TOTALS	Trawl	255	425	597	809	345	148	404	301	306	53	913	732
	Photography	981	1071	3920	1120	1464	2375	3658	1634	1643	1470	1389	3516



Central Transect Stations Ordered by Depth in Graphs	
Station	Depth (m)
C1	353
C6	525
C2	629
C3	866
C7	950
C8	1098
C9	1325
C4	1408
C10	1605
C11	2074
C5	2401
C12	2882





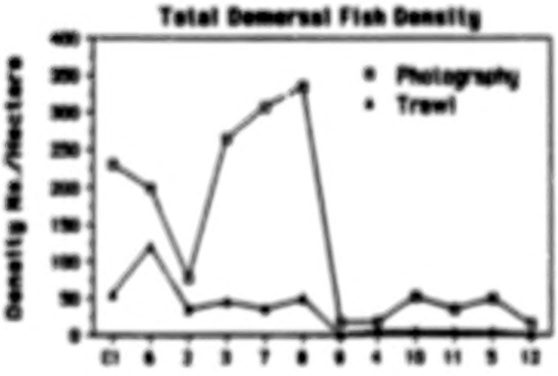


Figure 5-15. Megafauna density comparisons of trawl and benthic photography: Cruise III.

Cruise IV
Eastern Transect Stations
Ordered by Depth Groups

Station	Depth (m)
E1B	338
E1A	355
E1	356
E1C	360
E2A	624
E2	626
E2E	628
E2B	630
E2D	656
E2C	667
E3	808
E3C	847
E3D	853
E3A	854
E3B	867
E5	2900

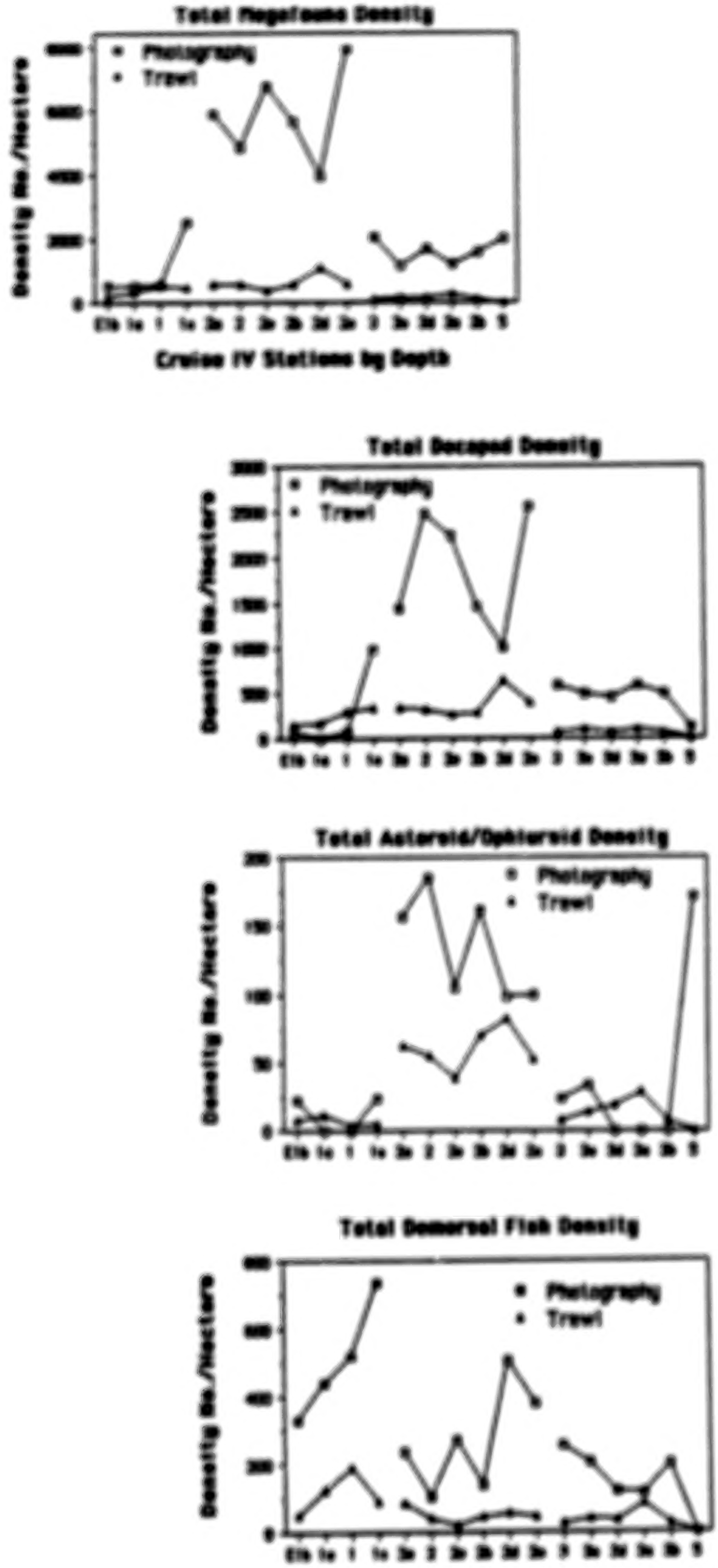
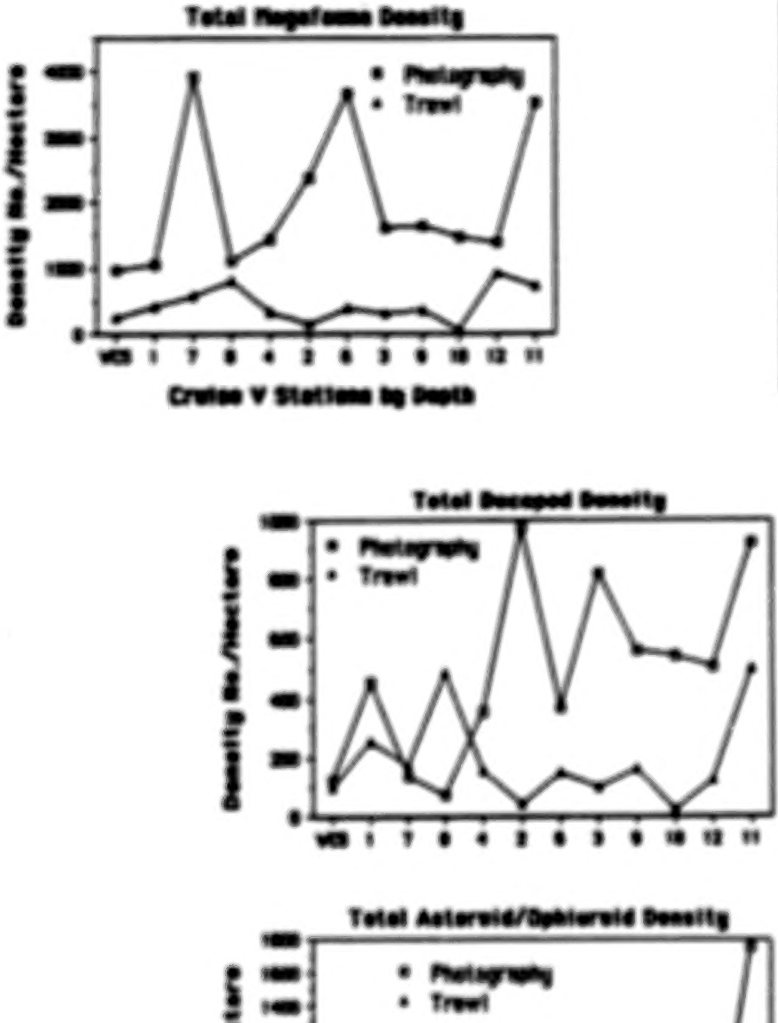


Figure 5-16. Megafauna density comparisons of trawl and benthic photography: Cruise IV.



Cruise V
West-Central Transect
Stations Ordered by Depth

Station	Depth (m)
WC5	278
WC1	338
WC7	417
WC8	445
WC4	479
WC2	515
WC6	552
WC3	748
WC9	767
WC10	807
WC12	1217
WC11	1231

Figure 5-17. Megafauna density comparisons of trawl and benthic photography: Cruise V.

trawl densities in these cases was, for the most part due to the small holothuroid, Peniagone sp. discussed previously. The density peak at Station C7 was due primarily to large aggregations of bivalves of the family Vesicomyidae not sampled by trawling.

Total megafauna densities from benthic photography exceeded that of trawling at all Cruise III stations, differing by no less than a factor of five at Station C1 (769 animals/ha and 154/ha, respectively, Table 5-15). Station C12 was not sampled by trawling. Other groups from Cruise III in Figure 5-15 also show benthic photography density estimates higher at all stations than those obtained from trawl samples. Total decapod density for Cruise III (Fig. 5-15) shows a very similar pattern for both sampling methods resulting in density maximums at Station C6 and secondary peaks at Station C8.

Density plots for combined asteroids and ophiuroids also resulted in similar patterns for both photography and trawling. Minimum densities appeared at Stations C1 and C10 and the maximum density occurred at Station C2 for both sampling types. The maximum asteroid/ophiuroid density in benthic photography resulted primarily from a single unidentified ophiuroid taxa (298 of 423 animals/ha). Similarly, a single species of ophiuroid, Ophiocamax fasciculata accounted for a density of 188 individuals/ha out of the total asteroid/ophiuroid trawl density of 194/ha.

Demersal fish densities at Cruise III stations were variable but generally low at Station C9 (1325 m) and deeper stations. Station densities calculated from benthic photography differed from trawling by a maximum of 12.5 times that of trawling at Station C5. The highest demersal fish density from photographs was recorded at Station C8 (336 fish/ha).

Figure 5-16 shows Cruise IV densities divided into the three major depth intervals, E1 stations (338-360 m), E2 stations (627-667 m) and E3 stations (809-867 m). Station E5 has data only from benthic photography and was not sampled by trawling.

Total megafauna at the top of Figure 5-16 shows the same general trend as Cruise III. Benthic photography densities exceeded trawl megafauna densities at all stations, but only by a small margin at three of the shallow stations. The density differences between the techniques were most pronounced at the mid-depth station group where all E2 station benthic photography densities exceeded those from trawling by a factor of at least 3.5 (Station E2D, Table 5-16).

The deeper, E3 station group also showed large differences between total megafauna densities obtained from photography and trawling. Benthic photography densities surpassed trawling values by factors of between 6 and 18 but overall, the density values were lower for both sample types compared to the mid-depth, E2 stations.

The three taxa selected for comparisons in Figure 5-16 show some variation in which trawling resulted in higher density estimates. For the decapod crustaceans, trawling samples resulted in higher density values at three stations, E1B, E1A and E1. The remaining Cruise IV stations were all represented by higher decapod densities derived from benthic photography.

For the asteroids and ophiuroids combined, a total of five stations were represented by higher densities resulting from trawl samples, Stations E1A and E1 of the shallow group and Stations E3D, E3A and E3B of the deep station group. All five of these differences were due to the fact that not a single asteroid or ophiuroid was photographed at these stations resulting in zero densities (Table 5-16). One of the highest densities for these groups was recorded from benthic photography at Station E5 (771/ha) which was not sampled by trawling.

Demersal fish densities at Cruise IV stations were all higher from benthic photography compared to densities from trawling. No fishes were observed in photographs at Station E5 but the remaining station densities calculated from benthic photography differed from trawling by factors between 1.3 (Station E3A) and 12.7 (Station E2E). The highest demersal fish density from photographs was recorded at Station E1C (737 fish/ha).

Cruise V total megafauna densities are shown at the top of Figure 5-17. The stations are arranged by depth between 278 and 1231 m but do not represent regular depth increments. The resulting general comparison of the two methodologies was the same as for Cruises III and IV; at all 12 Cruise V stations, total megafauna densities obtained from benthic photography analyses were higher than densities obtained from trawling.

Two peaks in megafauna density from benthic photography occurring at Stations WC7 and WC6 require special mention. At Station WC7, the bulk of the megafauna abundance resulted from a unique group of invertebrates, the Pogonophora/Vestimentifera. This group, included within "other invertebrates" in Table 5-17, accounted for 85% of the total megafauna density at that station (3342/tube worms/ha from a total megafauna density of 3920/ha). Tube worms were also obtained by trawling by the addition of a special device between the trawl doors designed to snag the animals which live partially buried below the surface at the sediment. This trawl device, certainly less efficient than photography, resulted in a density of only 52/ha for pogonophoran and vestimentiferan tube worms.

Station WC6 represented another anomalous area, particularly in context of the trawl sample at this station. A large volume of living scleractinian corals as well as a number of antipatharian corals were collected in the trawl. These were difficult to enumerate and are not fairly represented in the total megafauna density of 404 animals/ha from the trawl sample (Table 5-17). In contrast, the high total density represented for this station from benthic photography in Figure 5-17 was primarily the result of sea pens (2263/ha). The very high density of these alcyonarians (an order of magnitude higher than any other Cruise V station) may be related to the proximity of an area of abnormally high productivity sampled by the trawl at this station.

Decapod crustacean densities for Cruise V stations in Figure 5-17 show generally higher values from benthic photography as compared to trawling. Two stations were exceptions, WC7 and WC8 where trawl density estimates surpassed that of photography. The peak density of 973 decapods/ha (Table 5-17) occurred at Station WC2. The highest decapod density obtained from trawl samples (496/ha) was at the deepest station of Cruise V, Station WC11 which also showed a similar peak in density resulting from photography (925/ha).

Asteroid/ophiuroid densities were similar between the sampling methods at the four shallowest Cruise V stations (Fig. 5-17). Densities from photography were higher than from trawls for the remaining deeper stations with small peaks in photographc densities at Stations WC2 and WC9. The maximum density for asteroids/ophiuroids was at Station WC11 where large numbers of small ophiuroids were photographed (1731/ha, Table 5-17) but very few ophiuroids were collected in the trawl.

A similar pattern between benthic photography and trawling density estimates is shown for demersal fish in Figure 5-17. Densities from photography samples were higher at all Cruise V stations compared to trawl density estimates. The highest density for fish (480/ha) was seen at Station WC11 which was reflected by similar density peaks in the trawl sample.

5.3 QUALITATIVE RESULTS OF CRUISE I PHOTOGRAPHY

The overall quality of Cruise I photographs obtained by the Woods Hole Mini-Angus System did not permit the detailed benthic photography analyses as was performed on samples obtained from Cruises II-V that were obtained using the LGL BUCS apparatus. In general, the majority of the photographs obtained during Cruise I were at an extreme altitude (above 4 m) which prohibited both adequate lighting of the bottom and proper identification of any biota which appeared within individual frames. An unexpected problem also arose preventing accurate assessment of the area of each frame. During Cruise I, the Woods Hole Mini-Angus system provided altitude information as only a telemetered signal to the chart recorder on the surface and not as part of the data chamber information exposed onto each photograph. Due to the variation in altitude above the bottom from one frame to another, it was necessary to establish an exact correlation between the frame to be analyzed and the altitude mark on the chart recording. The difference in altitude between photographs taken eight seconds apart could easily be several meters which would translate into a large difference in area. If the wrong altitude was chosen from the confusing mass of tic marks representing camera altitudes on the chart record, resulting density estimates and size measurements could be grossly over- or underestimated. For these reasons it was necessary to utilize the photographs obtained from Cruise I, Stations C1-C5 in a qualitative or semi-qualitative descriptive manner only. The following brief accounts of each station include notable observations of dominant or unusual biota and general lebensspuren descriptions.

5.3.1 STATION C1

A total of 235 of the 800 possible frames were usable for a general description of this station during Cruise I. The total transect length was 2.31 nm. The dominant lebensspuren feature was white colored mounds of sediment in the shape of conical lumps. These lumps had apparently been excavated from underlying sediment of a lighter color than the surrounding surface. Other lebensspuren were composed of little other than these white-colored conical lumps. There were a few frames which had numerous small depressions but in general depressions were uncommon. The only other notable feature was long, narrow grooves or trails across many of the frames.

The most common animal was the hake Urophycis cirratus although only four were seen within the 235 usable frames. We observed three flatheads, Bembrops gobioides, and one large brachyuran crab (possibly the genus Pyromaia), several small shrimp swimming off the bottom (probably Penaeopsis serrata), and two unidentified sea pens within a single frame.

5.3.2 STATION C2

A total of 250 of the possible 800 frames at this station were suitable for interpretation. The transect covered a total distance of 0.94 nm. Station C2 was characterized by a much higher density of large depressions or burrows than at the shallower Station C1. These depressions were not generally arranged in any regular pattern (e.g., complete or partial circles) but in many frames, numerous depressions appeared in dense groups or clusters.

A large percentage of the observed lebensspuren appeared to be directly caused by a dominant large ophiuroid, possibly of the genus Ophiomusium. In numerous frames these ophiuroids apparently produced individual depressions with each of their five arms.

Tracks left behind by motile ophiuroids was another common feature. As a result of crawling along the bottom these ophiuroids produced series of short grooves regularly spaced from each other and at an angle to the direction of movement. Many photographic frames showed these features with the individual ophiuroids responsible in view.

What appeared to be a single ophiuroid producing the lebensspuren features mentioned above was by far the most abundant species. A total of 131 individual ophiuroids were enumerated from the 250 usable frames. The highest density was represented by a group of 10 individuals in a single frame with an estimated area of 14 m^2. Ophiuroids appeared in two separate aggregations along the photographic transect. The first aggregation was encountered after the first 29 min of the 110 min total transect time had elapsed. This aggregation continued for approximately 34 min or 31% of the total transect distance of 0.94 nm equivalent to a linear distance of 1770 m. The second aggregation did not occur until 32 min after the first had ended. The gap between the aggregations was 1656 m. The second aggregation continued until the end of the transect resulting in a minimum aggregation size of 857 m.

Other megafauna observed at Station C2 included two starfish which both appeared to be *Persephonaster echinulatus*. This species was also obtained from trawl samples at Station C2 during Cruise I. Only a single shrimp was observed in the 250 frames. Two pagurid crabs, *Parapagurus*, were observed with attached commensal anemones. Other invertebrates included a single unidentified zoantharian anemone, a single unidentified echinoid and a single holothuroid, *Mesothuria*.

Two large macrourid fish were recorded but could not be further identified due to the high altitude of the photographs. Two eels, *Synaphobranchus*, were recorded. Two other fish were observed but could not be distinguished in any detail. One appeared to be in the family Alepocephalidae.

5.3.3 STATION C3

A total of 1.66 nm were transected at this station but only 113 frames were in view of the bottom and even fewer were below an altitude of 5 m, permitting detailed observation of the substrate or biota. In general, the dominant lebensspuren features consisted of rounded depressions or burrows in apparent random arrangement without recognizable symmetry or patterns.

The biota observed in the 113 frames included three shrimp, one of which was the genus *Glyphocrangon*, two small ophiuroids with short white arms, one holothuroid (*Mesothuria*) and four fish. The fish included two *Synaphobranchus*, one *Halosaurus*, and one large unidentified macrourid, probably *Nezumia*.

One very unusual photograph was obtained from the supplementary second camera equipped with a wide angle 16 mm lens. A fairly large holothuroid was photographed while completely off the bottom. Although it is common for smaller holothuroids (2-3 cm *Peniagone*) to be found in the water column, this larger individual appeared to be on the order of 20 cm in length. A small sediment plume could be seen below where it had launched itself off the bottom.

5.3.4 STATION C4

A total of 208 frames were acceptable for use in the general description of this station. The transect covered a total distance of 2.32 nm. The substrate was highly bioturbated in comparison to previous Stations C1-C3 showing considerable texture and a general bumpy nature. The major lebensspuren features included depressions and conical lumps but these occurred only in low density. Other than small-scale texturing of the sediment, most of the substrate surface was relatively unfeatured. White colored sediment patches were evident due to their contrast in color, though they did not have much relief. Visible evidence of bottom water currents was photographed in some areas of the transect. In these photographs, small features or objects projecting above the bottom produced tails of accumulated sediments (lineations) to one side of the features only. These features can be produced by strong bottom currents transporting resuspended sediments which are then redeposited on the down current sides of objects. The deposition occurs as a result of the reduced energy due to turbulence (and ability to keep sediment in suspension) as the water current flows over and around an obstruction or depression. In one frame, a stalked object, possibly a dead pogonophoran worm tube or a sea pen had produced a depression in the sediment where it had been pushed back and forth by water movement.

In some segments of the transect in proximity to those showing lineation features, there was also evidence of bottom scouring. These frames exhibited a very rough texture in comparison to the fine grain nature of the sediment typical of previous Cruise I Stations C1-C3. Evidence of scouring and resulting sediment lineations in some frames appeared to be restricted to relatively small areas. The beginning of the transect showed the more common fine grain sediment texture indicating the absence of significant bottom currents.

One of the components of the coarse material evident in the majority of the transect was small, white colored fragments many of which had the shape and features of pteropod shells. These white, presumably calcareous objects were very numerous in some frames with estimated densities in the range of several hundred fragments per m^2.

At one point along the transect there were large (1 m) lumps of mud projecting above the bottom with relief of approximately 0.2-0.5 m. These large displaced portions of sediment with resulting trenches and large depressions may be the result of localized down-slope slumping of unstable sediment layers known to occur in this area of the continental slope south of Louisiana.

Megafauna was relatively abundant at this station with the holothuroid *Peniagone* by far the dominant taxa. The highest density of *Peniagone* was in a single frame with 30 individuals in an estimated area of 2.0 m^2 representing a density of approximately 15 per m^2. A total of 560 individuals were enumerated from the 208 frames. However, they were not evenly dispersed throughout the transect. One cluster of holothuroids began about one-third into the 2.32 nm transect and continued for approximately 266 m over the following 7 min of the transect drift. The second cluster did not occur until after a 647 m gap in the transect. This second cluster of *Peniagone* continued in all visible photographic frames for the following 6 min representing a transect distance of 228 m. In the last 5 min of the transect (190 m in length) there was one other aggregation of *Peniagone*, with one frame containing 45 individuals in an estimated area of 3.5 m^2.

There was also a variety of other biota enumerated in the 208 usable frames at this station. Invertebrates included three glass sponges *Hyalonema* sp., three worm tubes, *Hyalinoecia tubicola* and two other worm tubes which appeared to be pogonophorans. There were a total of six shrimp observed, four of which were unidentifiable, either caridean or penaeid but one was of the genus *Glyphocrangon* and another large shrimp was the genus *Plesiopenaeus*. Echinoderms other than the 560 *Peniagone* included one unidentified crinoid and three ophiuroids of the same species with white colored arms.

Fishes observed at Station C4 included one *Synaphobranchus*, one hake (Gadidae), and two unidentified individuals, one of which was eel-shaped, perhaps a small *Synaphobranchus*.

5.3.5 STATION C5

A large number of frames were lost at this station due to starting the camera at the surface before lowering to the bottom depth of 2470 m at this station while continually taking photographs along the way. The 178 remaining frames were especially significant due to a poor trawl deployment at this station.

The general texture of the flat and unfeatured bottom sediment appeared very flocculent with very few burrows. Of the few depressions that were observed, many were arranged in very distinct circular patterns usually forming a complete ring of between five and seven burrows, typically six. The dominant lebensspuren were the trails left behind, by holothuroids, asteroids (complete with the impressions of tube feet), taxa not readily identified by their trails and tracks. Fecal deposits from holothuroids were relatively common.

Biota enumerated from the 178 usable frames primarily included echinoderms. Only one taxa of holothuroid was actually seen in the photographs; *Pelopatides*, a spectacular specimen *in situ*. Apparently this genus is either lost by passing completely through the net during trawling or the remaining animal tissue is so unconsolidated it cannot be identified in trawl samples; there was never a single specimen collected from trawls throughout the entire project.

Other invertebrates were recorded including three unidentified sea pens and a single shrimp, *Plesiopenaeus armatus*. A single asteroid, *Plutonaster intermedius*, was recorded. No fish were seen in any of the visible frames at Station C5.

6.0 REFERENCES

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Anderson, R.K., R.S. Scalan, P.L. Parker and E.W. Behrens. 1983. Seep oil and gas in Gulf of Mexico slope sediments. Science. 222:619-621.

Backus, R.H., G.W. Mead, R.L. Haedrich, A.W. Ebeling. 1965. The mesopelagic fishes collected during Cruise 17 of the R/V CHAIN, with a method for analyzing faunal transects.

Bartlett, M.S. 1975. The statistical analysis of spatial patterns. Chapman and Hall, London. 90 p.

Berg, C.J., Jr. 1985. Reproductive strategies of mollusks from abyssal hydrothermal vent communities. Biol. Soc. Wash., No. 6:185-197.

Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. Spec. Sci. Rep. No. 77 Va. Inst. Mar. Sci. EPA-600/3-77-033.

Boland, G.S., B.J. Gallaway, J.S. Baker and G.S. Lewbel. 1983. Ecological effects of energy development on reef fish of the Flower Garden Banks. Natl. Mar. Fish. Ser. Contract NA80-GA-C-00057.

Boss, K.J. 1968. New species of Vesicomyidae from the Gulf of Darien, Caribbean Sea (Bivalvia: Mollusca). Bull. Mar. Sci. 18(3):733-748.

Boss, K.J. and R.D. Turner. 1981. The giant white clam from the Galapagos Rift: Calyptogena magnifica species novum. Malacologia. 20(1):161-194.

Bowman, K.O., K. Hutcheson, E.P. Odum and L.R. Shenton. 1971. Comments on the distribution of indices of diversity. P. 315-359. In: G.P. Patil, E.C. Pielou and W.E. Waters (Eds.), Statistical Ecology, Vol. 3. Pennsylvania State Universsity Press, University Park.

Bradbury, M.G. 1967. The genera of batfishes (Family Ogcocephalidae). Copeia. (2):399-422.

Bradbury, M.G. 1978. Ogcocephalidae. In: W. Fischer (Ed.), FAO Species Identification sheets for fishery purposes, western Central Atlantic (fishing area 31). Volume III.

Bright, T.J. 1968. A survey of the deep sea bottom fishes of the Gulf of Mexico below 350 meters. Texas A&M University, Ph.D. Dissertation. pp. vii + 218.

Bright, T.J. 1970. Food of deep-sea bottom fishes. In: W.E. Pequegnat and F.A. Chace, Jr. (Eds.), Contributions on the biology of the Gulf of Mexico. Texas A&M University Oceanogaphic Studies. 1:245-252.

Brooks, J.M., M.C. Kennicutt II, R.R. Fay, T.J. McDonald and R. Sassen. 1984. Thermogenic gas hydrates in the Gulf of Mexico. Science. 225:409-411.

Brooks, J.M., M.C. Kennicutt II and R.R. Bidigare. 1986. Study of chemosynthetic marine ecosystems in the Gulf of Mexico. Final cruise report for Offshore Operators Committee.

Bruun, A.F. 1957. Chapter 22. Deep sea and abyssal depths. P. 641-672. *In*: S.W. Hedgpeth (Ed.), Treatise on marine ecology and paleoecology. Vol. 1. Ecology. Geological Society of America Memoir 67. 1296 p.

Bureau of Commercial Fisheries (BCF). 1969. R/V *Oregon II* summary cruise report, Cruise 9. Bureau of Commercial Fisheries - Region II, Exploratory Fishing and Gear Research Base Headquarters, Pascagoula, Mississippi.

Calder, J.A. and P.L. Parker. 1968. Stable carbon isotope ratios as indices of petrochemical pollution in aquatic systems. Environ. Sci. Technol. 2:535-539.

Chace, F.A., Jr. 1940. Reports on the scientific results of the first Atlantis expedition to the West Indies, under the joint auspices of the University of Havana and Harvard University. The brachyuran crabs. Torreia 4:3-67.

Childress J.J., C.R. Fisher, J.M. Brooks, M.C. Kennicutt II, R. Bidigare and A. Anderson. 1986. A methanotrophic marine molluscan symbiosis: mussels fueled by gas. Science (in press).

Cochran, W.G. 1977. Sampling techniques. John Wiley and Sons, New York. 428 p.

Corliis, J.B., J. Dymond, L. Gordon, J.M. Edmond, R.P. von Herzen, R.D. Ballard, K. Green, D. Williams, A. Bainbridge, K. Crane and T.H. Van Andel. 1979. Submarine thermal springs on the Galapagos Rift. Science 203:1073-1083.

Coull, B.C. 1970. Shallow water meiobenthos of the Bermuda platform. Oecologia 4:325-357.

Cox, D.R. 1961. Test of separate families of hypotheses. Proc. 4th Berkeley Symp. 1:105-123.

Crosnier, A. 1978. Crustaces decapodes peneides Aristeidae (Benthesicyminae, Aristeinae, Solenocerinae). Faune de Madagascar No. 46; Centre National de la Recherche Scientifique, and Office de la Recherche Scientifique et Technique Outre-Mer, Paris.

DeNiro, M.J. and S. Epstein. 1978. Influence of diet on the distribution of carbon isotopes in animals. Geochim. Cosmochim. Acta 42:495-506.

Dinet, A. and M.H. Vivier. 1977. Le meiobenthos abyssal du Golfe de Gascogne. I. Considerations sur les donnees quantitatives. Cak. Biol. Mar. 18:85-97.

Ekdale, A.A., L.N. Muller and M.T. Novak. 1984. Quantitative ichnology of modern pelagic deposits in the abyssal Atlantic. Paleogeogr., Palaeoclimatol., Palaeoecol. 45:189-223.

Ewing, M. and R.A. Davis. 1967. Lebensspuren photographed on the ocean floor. P. 259-294. *In*: J.B. Hersey (ed.), Deep-Sea photography. John Hopkins Press, Baltimore. 310 p.

Fauble, A. 1982. Determination of individual meiofauna dry weight values in relation to definite size classes. Cahierms de Biologie Marine, Tome XXIII:339-345.

Firth, R.W. and W.E. Pequegnat. 1971. Deep-sea lobsters of the families Polychelidae and Nephropidae (Crustacea, Decapoda) in the Gulf of Mexico and Caribbean Sea. Tech. Rep. No. 71-11T to US Navy Office of Naval Research, Washington, D.C., from Texas A&M Research Foundation, College Station, TX. 106 p.

Fry, B. and P.L. Parker. 1979. Annual diet in Texas seagrass systems: ^{13}C evidence for the importance of benthic plants. Estuarine Mar. Sci. 8:499-509.

Fry, B. 1981. Natural stable isotope tag traces Texas shrimp migration. Fishery Bull. 79:337-345.

Gage, J.D. 1986. The benthic fauna of the Rockall Trough: regional distribution and bathymetric zonation. Proc. Royal Soc. of Edinburgh. 88B:159-174.

Gearing, J.N., P.J. Gearing, D.T. Rudnick, A.G. Requeijo and M.J. Hutchins. 1984. Isotopic variability of organic carbon in a phytoplankton-based temperate estuary. Geochim. Cosmochim. Acta. 38:1089-1098.

Grassle, J.F. 1985. Hydrothermal vent animals: Distribution and biology. Science. 229(4715):713-717.

Grassle, J.F. and W. Smith. 1976. A similarity measure sensitive to the contribution of rare species and its use in investigation of variation in marine benthic communities, Oecologia. 25:13-22.

Grassle, J.F. 1983. Introduction to the biology of hydrothermal vents. P. 665-675. *In*: P.A. Rona, K. Bostrom, L. Laubier and K.L. Smith (eds.), Hydrothermal processes at seafloor spreading centers. Plenum Press, New York.

Grassle, J.F., H.L. Sanders, R.R. Hessler, G.T. Rowe and T. McLellan. 1975. Pattern and zonation: a study of the bathyal megafauna using the research submersible *Alvin*. Deep-Sea Research. 22:457-481.

Haines, E.B. 1976. Relation between the stable carbon isotope composition of fiddler crabs, plants, and soils, in a salt marsh. Limnol. Oceanogr. 4:880-883.

Haines, E.B. and C.L. Montague. 1979. Food sources of estuarine invertebrates analyzed using $^{13}C/^{12}C$ ratios. Ecology. 60:48-56.

Hecker, B. 1985. Fauna from a cold sulfur-seep in the Gulf of Mexico: comparisons with hydrothermal vent communities and evolutionary implications. Biol. Soc. Wash., No. 6:465-473.

Heezen, B.C. and C.D. Hollister. 1971. The face of the deep. Oxford University Press. 659 pp.

Hessler, R.R. and W.M. Smithy, Jr. 1983. The distribution and community structure of megafauna at the Galapagos Rift hydrothermal vents. P. 735-770. In: P.A. Rona, K. Bostrom, L. Laubier and K.L. Smith (eds.), Hydrothermal processes at seafloor spreading centers. Plenum Press, New York.

Hessler, R.R., W.M. Smithy and C.H. Keller. 1985. Spatial and temporal variation of giant clams, tubeworms and mussels at deep-sea hydrothermal vents. Biol. Soc. Wash. Bull. 6:411-428.

Hollister, C.D. and I.N. McCave. 1984. Sedimentation under deep-sea storms. Nature. 309:220-225.

Houston, K.A. and R.L. Haedrich. 1986. Food habits and intestinal parasites of deep demersal fishes from the upper continental slope east of Newfoundland, northwest Atlantic Ocean. Marine Biology 92:563-574.

Hutcheson, K. 1970. A test for comparing diversities based on the Shannon formula. J. Theor. Biol. 29:151-154.

Iwamoto, T. 1970. Macrourid fishes of the Gulf of Guinea. Studies in tropical oceanography. No. 4, Part 2:316-431.

Jannasch, H.W. 1983. Microbial processes at deep-sea hydrothermal vents. P. 677-709. In: P.A. Rona, K. Bostrom, L. Laubier and K.L. Smith (eds.), Hydrothermal processes at seafloor spreading centers. Plenum Press, New York.

Jannasch, H.W. 1984. Chemosynthesis: the nutritional basis for life at deep-sea vents. Oceanus. 27(3):73-78.

Jones, M.L. 1981. Riftia pachyptila Jones: observations on the vestimentiferan worm from the Galapagos Rift. Science. 213:333-336.

Jones, M.L. 1984. The giant tubeworms. Oceanus 27(3):47-53.

Jones, M.L. 1985. On the Vestimentifera, new phylum: six new species, and other taxa, from hydrothermal vents and elsewhere. Biol. Soc. Wash., No. 6:117-158.

Jumars, P.A. and J.E. Eckman. 1983. Spatial structure within deep-sea benthic communities. P. 399-452. In: G.T. Rowe (ed.), Deep-sea biology. John Wiley and Sons, New York.

Kennicutt II, M.C., J.M. Brooks, R.R. Bidigare, R.R. Fay, T.L. Wade and T.J. McDonald. 1985. Vent-type taxa in a hydrocarbon seep region on the Louisiana slope. Nature. 317(6035):351-353.

Kensley, B. 1981. On the zoogeography of southern African decapod crustacea, with a distributional checklist of the species. Smithsonian Cont. Zool. No. 338. 64 p.

LGL Ecological Research Associates, Inc. and Texas A&M University. 1985. Annual report for northern Gulf of Mexico continental slope study. Annual report to Minerals Management Service, U.S. Dept. of Interior, Contract 14-12-0001-30046. 290 p.

Lutz, R.A., D. Jablonski and R.D. Turner. 1984. Larval development and dispersal at deep-sea hydrothermal vents. Science. 226(4681):1451-1453.

Lutz, R.A. 1985. Molluscan growth at deep-sea hydrothermal vents. Biol. Soc. Wash. No. 6:199-210.

Lutz, R.A., W. Lowell and D.C. Rhoads. 1985. Molluscan growth at deep-sea hydrothermal vents. Biol. Soc. Wash., No. 6:199-210.

MacDonald, A.G. 1975. Physiological aspects of deep sea biology. Cambridge Univ. Press. Cambridge. 450 pp.

Marshall, N.B. 1965. Systematic and biological studies of the macrourid fishes (Anacanthini-Teleostii). Deep-Sea Research. 12:299-322.

Marshall, N.B. 1979. Developments in deep-sea biology. Blandford Press.

Marshall, N.B. and T. Iwamoto. 1973. Family Macrouridae. P. 496-666. In: Fishes of the western North Atlantic. Sears Foundation for Marine Research, Memoir No. 1, Part 6.

Martin, D.M. 1984. Distribution and ecology of the Synaphobranchidae of the Gulf of Mexico. Gulf Research Reports. 7(4):311-324.

Mauchline, J. and J.D.M. Gordan. 1984. Diets and bathymetric distributions of the mcrourid fish of the Rockall Trough, northeastern Atlantic Ocean. Marine Biology. 81:107-121.

Mauchline, J. and J.D.M. Gordan. 1985. Trophic diversity in deep-sea fish. J. Fish. Biol. 26:527-535.

Mauchline, J. and J.D.M. Gordan. 1986. Foraging strategies of deep-sea fish. Marine Ecology, Progress Series. 27:227-238.

Mayo, B.S. 1974. The systematics and distribution of the deep-sea genus Munidopsis (Crustacea, Galatheidae) in the western Atlantic Ocean. Ph.D. dissertation, Univ. Miami, Coral Gables, Florida. p. 255-265.

Mead, G.W. 1966. Family Chlorophthalmidae. P. 162-189. In: Fishes of the western North Atlantic. Searss Foundation for Marine Research, Memoir No. 1, Part 5.

Middleton, R.W. and J.A. Musick. 1986. The abundance and distribution of the family Macrouridae (Pisces: Gadiformes) in the Norfolk Canyon Area. Fishery Bulletin. 84(1):35-62.

Morrison, J.M., W.J. Merrell, Jr., R.M. Key and T.C. Key. 1983. Property distributions and deep chemical measurements within the western Gulf of Mexico. Journ. Geophys. Res. 88, No. C3.

Parker, P.L. 1964. The biogeochemistry of the stable isotopes of carbon in a marine bay. Geochim. Cosmochim. Acta. 18:1155-1164.

Paull, C.K., B. Hecker, R. Commeau, R.P. Freeman-Lynde, C. Neumann, W.P. Corso, S. Golubic, J.E. Hook, E. Sikes and J. Curray. 1984. Biological communities at the Florida Escarpment resemble hydrothermal vent taxa. Science. 226:965-967.

Paul, C.K., A.J.T. Jull, L.J. Toolin and T. Linick. 1985. Stable isotope evidence for chemosynthesis in an abyssal seep comunity. Nature. 317:709-711.

Pemberton, S. George and Robert W. Fry. 1984. Quantitative methods in ichnology: spatial distribution among populations. Lethaia. Vol. 17, pp. 33-49. Oslo. ISSN 0024-1164.

Pequegnat, W.E. 1983. The ecological communities of the continental slope and adjacent regimes of the northern Gulf of Mexico, prepared by TerEco Corp. for Minerals Management Service, U.S. Dept. of Interior Contract AA851-CT1-12. 398 pp. + appendices.

Pequegnat, W.E. and F.A. Chace, Jr. 1970. Contributions on the biology of the Gulf of Mexico. Texas A&M University Oceanographic Studies, Vol. 1. Gulf Publishing Company, Houston, Texas. xv + 270 p.

Pequegnat, W.E. and L.H. Pequegnat. 1971. New species and new records of *Munidopsis* (Decapoda:Galatheidae) from the Gulf of Mexico and Caribbean Sea. Texas A&M Univ. Oceanogr. Studies, 1 (Suppl.):1-24. Gulf of Publishing Co., Houston, TX.

Pequegnat, W.E., L.H. Pequegnat, R.W. Firth, Jr., B.M. James and T.W. Roberts. 1971. Gulf of Mexico deep-sea fauna: Decapoda and Euphausiacea. Serial atlas of the marine environment, Folio 20, American Geographical Society. 12 p. + 6 pl.

Pielou, E.C. 1969. An introduction to mathematical ecology. Wiley, New York.

Powell, E.N., T.J. Bright and J.M. Brooks. 1986. The effect of sulfide and an increased food supply on the meiofauna and macrofauna at the East Flower Garden brine seep. Helgolander Meeresuntersuchungen 40:57-82.

Powers, L.W. 1977. A catalogue and bibliography to the crabs (Brachyura) of the Gulf of Mexico. Cont. Marine Sci., Suppl. to Vol. 20. 190 p.

Rao, C.R. 1973. Linear statistical inference and its application. John Wiley & Sons, New York. 625 p.

Rau, G.H. 1981. Hydrothermal vent clam and tube worm $^{13}C/^{12}C$: further evidence of non-photosynthetic food sources. Science. 213:338-340.

Rau, G.H. and J.I. Hedges. 1979. Carbon-13 depletion in a hydrothermal vent mussel: Suggestions of a chemosynthetic food source. Science. 203:648-649.

Rayburn, R. 1975. Food of deep-sea demersal fishes of the northwestern Gulf of Mexico. Texas A&M University Masters Thesis. pp. vi + 119.

Rex, M.A. 1983. Geographic patterns of species diversity in the deep-sea benthos. _In_: Gilbert T. Rowe (ed.), The Sea. Vol. 8. Deep-Sea Biology. John Wiley & Sons, New York.

Ripley, B.D. 1980. Spatial statistics. John Wiley & Sons, New York. 252 p.

Rosman, I.R., G.S. Boland and J.S. Baker. (In Press). Epifaunal aggregations of Vesicomyidae on the continental slope off Louisiana. Deep Sea. Res.

Rowe, G.T. and D.W. Menzel. 1971. Quantitative benthic samples from the deep Gulf of Mexico with some comments on the measurement of deep-sea biomass. Bull. Mar. Sci. 21:556-566.

Rowe, G.T., P.T. Polloni and S.G. Horner. 1974. Benthic biomass estimates from the northwestern Atlantic Ocean and the northern Gulf of Mexico. Deep-Sea Research. 21:641-650.

Sackett, W.M., S. Nakaparksin and D. Dalrymple. 1970. Carbon isotope effects in methane production by thermal cracking. P. 37-53. _In_: G.D. Hobson and G.C. Speers (Eds.), Advances in organic geochemistry, 1966. Pergamon Press.

Smith, C.R. and S.C. Hamilton. 1983. Epibenthic megafauna of a bathyal basin off southern California: patterns of abundance, biomass and dispersion. Deep-Sea Research. 30:907-928.

Soto, L.A. 1985. Distributional patterns of deep-water brachyuran crabs in the Straits of Florida. J. Crust. Biol. 5(3):480-499.

Spies, R.B. and D.J. DesMarais. 1983. Natural isotope study of trophic enrichment of marine benthic communities by petroleum seepage. Marine Biology. 873:67-71.

Serfling, R.J. 1980. Approximation theorems of mathematical statistics. John Wiley & Sons, New York. 371 p.

Suess, E., B. Carson, S.D. Ritger, J. Casey Moore, M.L. Jones, L.D. Kulm and G.R. Cochrane. 1985. Biological communities at vent sites along the subduction zone off Oregon. Biol. Soc. Wash. No. 6:475-484.

Thiel, H. 1983. Meiobenthos and nanobenthos of the deep sea. In: G.T. Rowe (Ed.), Deep-Sea biology. Chap. 5. John Wiley and Sons, New York.

Tietjen, J.H. 1969. The ecology of shallow-water meiofauna of two New England estuaries. Oecologia. 2:251-291.

Tietjen, J.H. 1971. Ecology and distribution of deep-sea meiobenthos off North Carolina. Deep-Sea Res. 18:941-954.

Tunnicliffe, V., S.K. Juniper and M.E. deBurgh. 1985. The hydrothermal vent community on Axial Seamount, Juan de Fuca Ridge. Biol. Soc. Wash. No. 6:453-464.

Uzmann, J.R., R.A. Cooper, R.B. Theroux and R.L. Wigley. 1977. Synoptic comparison of three sampling techniques for estimating abundance and distribution of selected megafauna: submersible vs camera sled vs otter trawl. Mar. Fish. Rev. 39(12):11-19.

Wenner, E.L. n.d. Notes on the distribution and biology of Galatheidae and Chirostylidae (Decapoda: Anomura) from the Middle Atlantic Bight. Unpub. ms., Virginia Institute of Marine Science and School of Marine Science, College of William and Mary, Gloucester Point, Virginia.

Wigley, R.L. and A.D. McIntyre. 1964. Some quantitative comparisons of offshore meiobenthos and macrobenthos south of Martha's Vineyard. Limnol. Oceanogr. 9:485-493.

Wigley, R.L. and J.L. Messersmith. 1976. Benthochascon schmitti Rathbun (Decapoda, Brachyura) off southern New England. Crustaceana. 31:111-112.

Williams, A.B. 1984. Shrimps, lobsters, and crabs of the Atlantic coast of the eastern United States, Maine to Florida. Smithsonian Institution Press, Washington, D.C. xvii + 550 p.

Williams, A.B. and R.L. Wigley. 1977. Distribution of decapod crustacea off northeastern United States based on specimens at the Northeast Fisheries Center, Woods Hole, Massachusetts. NOAA Tech. Rep. NMFS Circular 407. National Oceanic and Atmospheric Administration, Natinal Marine Fisheries Service, Washington, D.C. 44 p.

Williams, P.M., K.L. Smith, E.M. Druffel and T.W. Linick. 1981. Dietary carbon sources of mussels and tubeworms from Galapagos hydrothermal vents determined from tissue ^{14}C activity. Nature. 292:448-452.

7.0 ATTACHMENTS

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ATTACHMENT A1.0: Supportive Data, Section 3.0

A1.1: Hydrographic Profiles by Cruise

A1.2: Sediment Data

ATTACHMENT A2.0: Supportive Data, Section 4.0

A2.1: Summary of Macrofaunal Densities (no/m^2) by Major Taxonomic Group, Cruises I-V

A2.2: Summary of Macrofaunal Taxa by Station and Cruise

A2.3: Summary of Macrofaunal Diversity Data by Station and Cruise

A2.4: Polychaete Feeding Types

A2.5: Depth Ranges of 150 Most Abundant Polychaetes

A2.6: Polychaete References

A2.7: Annotated List of Abundant Polychaete Species

A2.8: Distribution of Abundant Polychaete Species

A2.9: Summary of Invertebrate Species Found in Trawl

A2.10: Summary of Fish Species Found in Trawl

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ATTACHMENT A1.0: Supportive Data, Section 3.0

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ATTACHMENT A1.1: Hydrographic Profiles by Cruise

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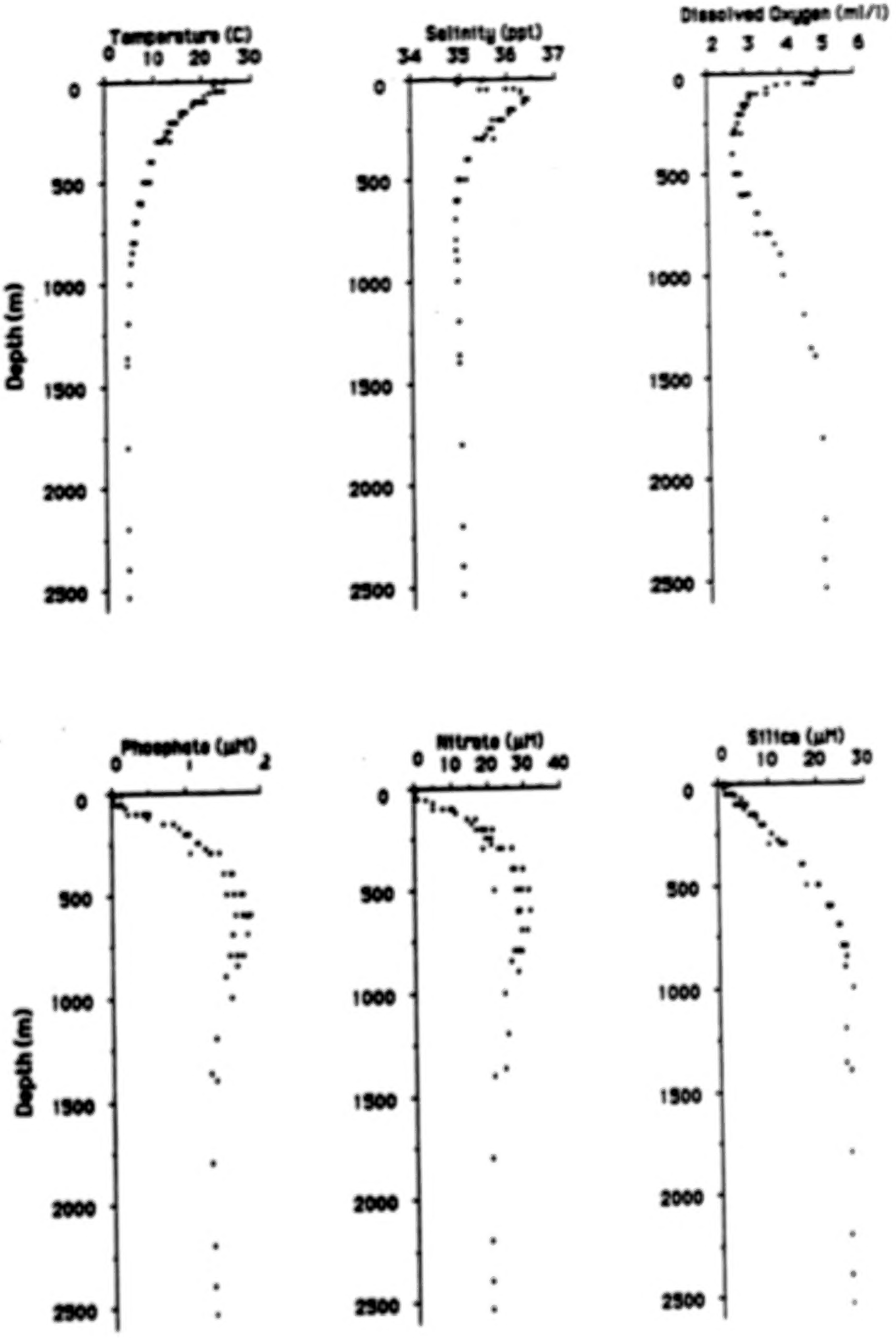
Cruise I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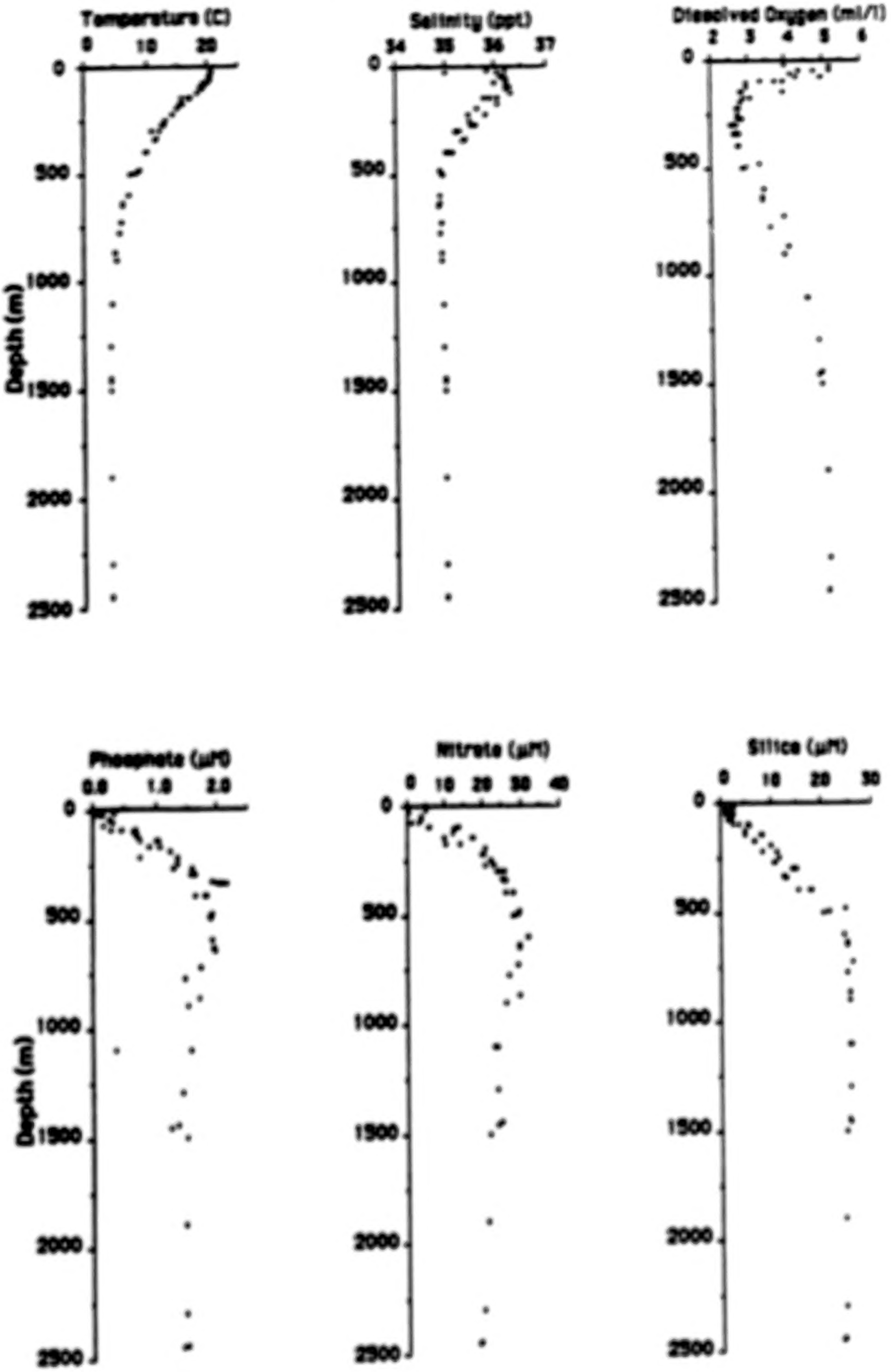
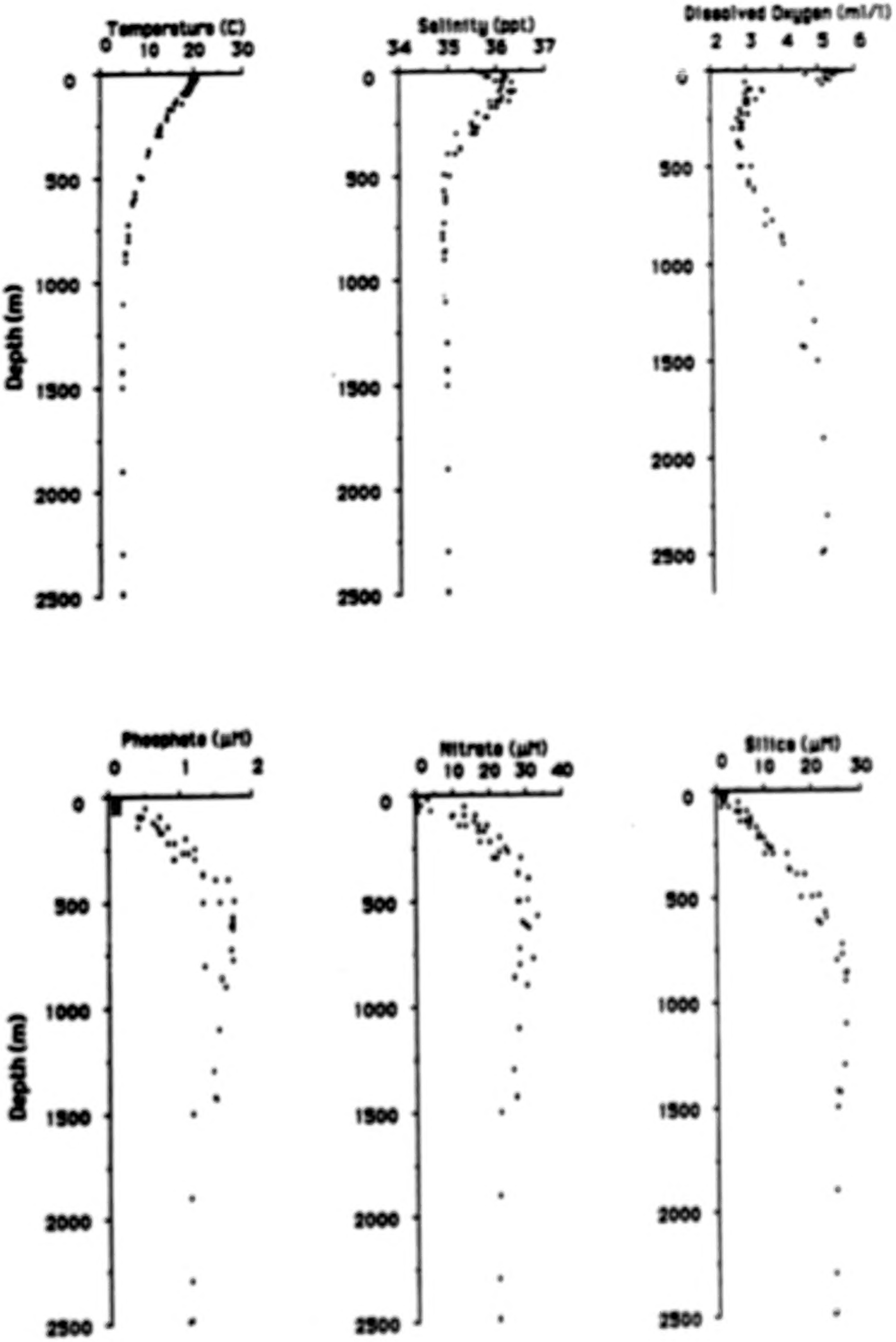
10
20
30
Salinity (ppt)
34
35
36
37
Dissolved Oxygen (ml/l)
2
3
4
5
6
Depth (m)
0
500
1000
1500
2000
2500
Phosphate (µM)
0
1
2
Nitrate (µM)
0
10
20
30
40
Silica (µM)
0
10
20
30

Cruise II - Western Transect



Cruise II - Central Transect



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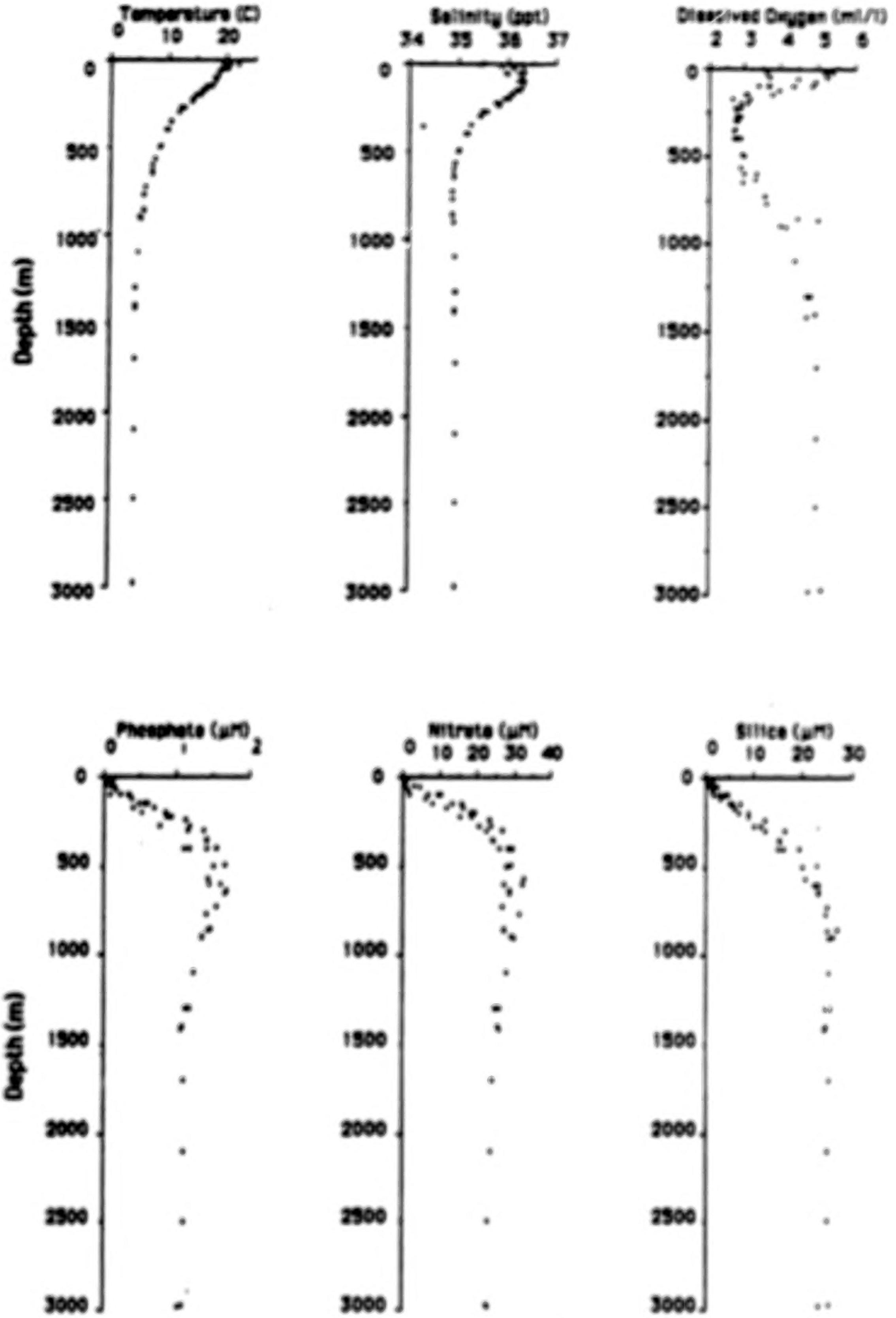

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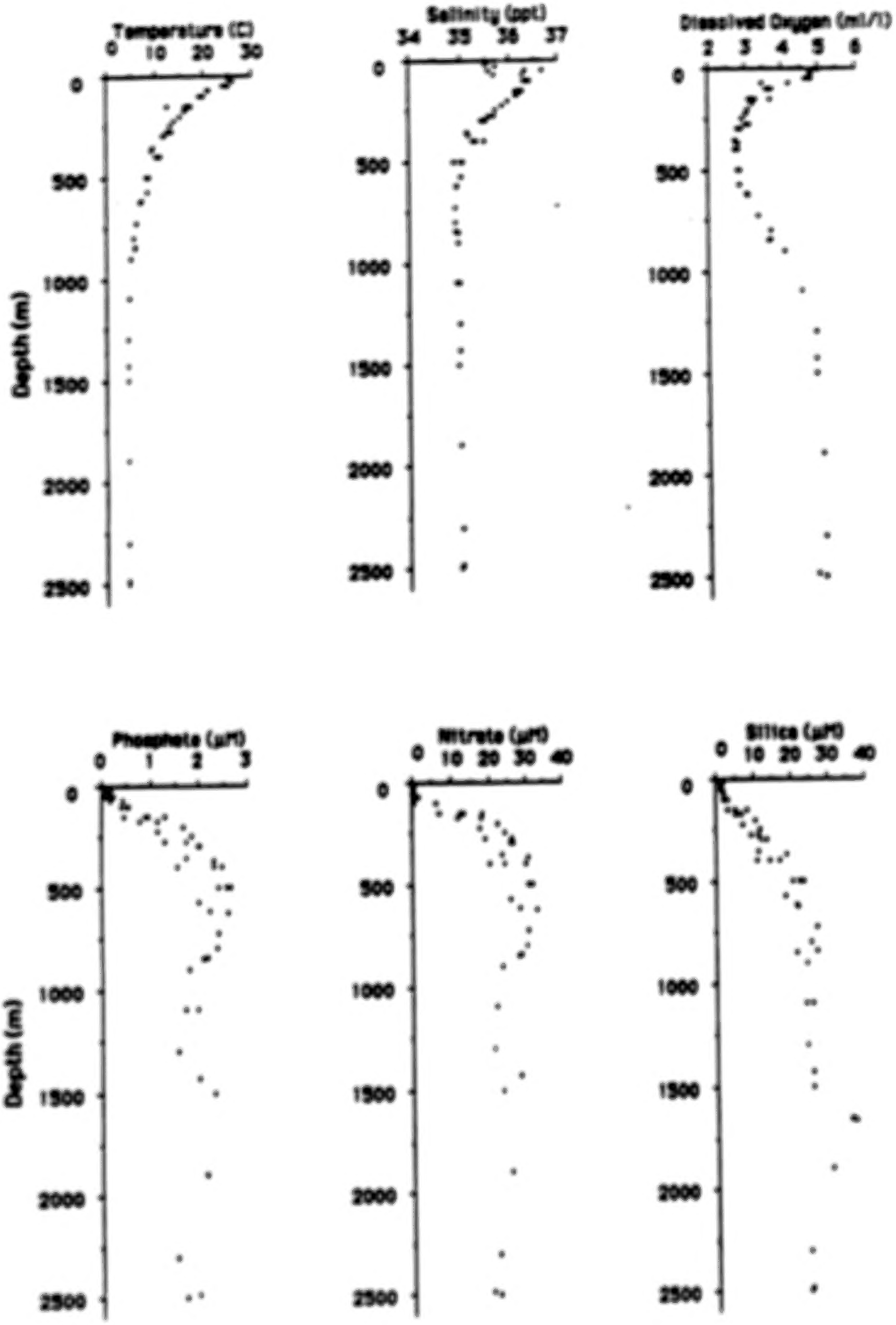
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10
20
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Salinity (ppt)
34
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37
Dissolved Oxygen (ml/l)
2
3
4
5
6
Depth (m)
0
500
1000
1500
2000
2500
Phosphate (µM)
0
1
2
3
Nitrate (µM)
0
10
20
30
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Silica (µM)
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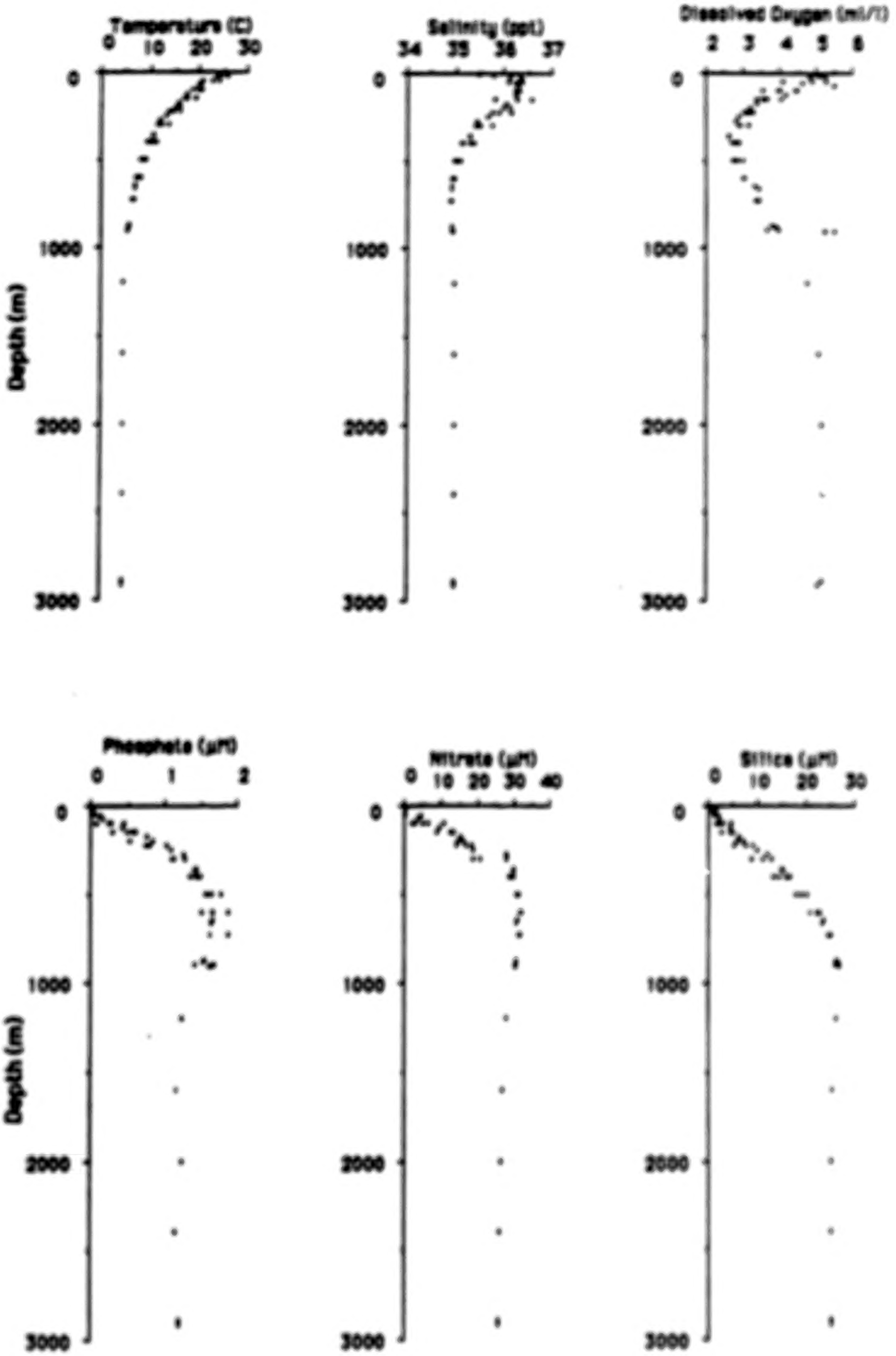
10
20
30
40

Cruise IV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Salinity (ppt)
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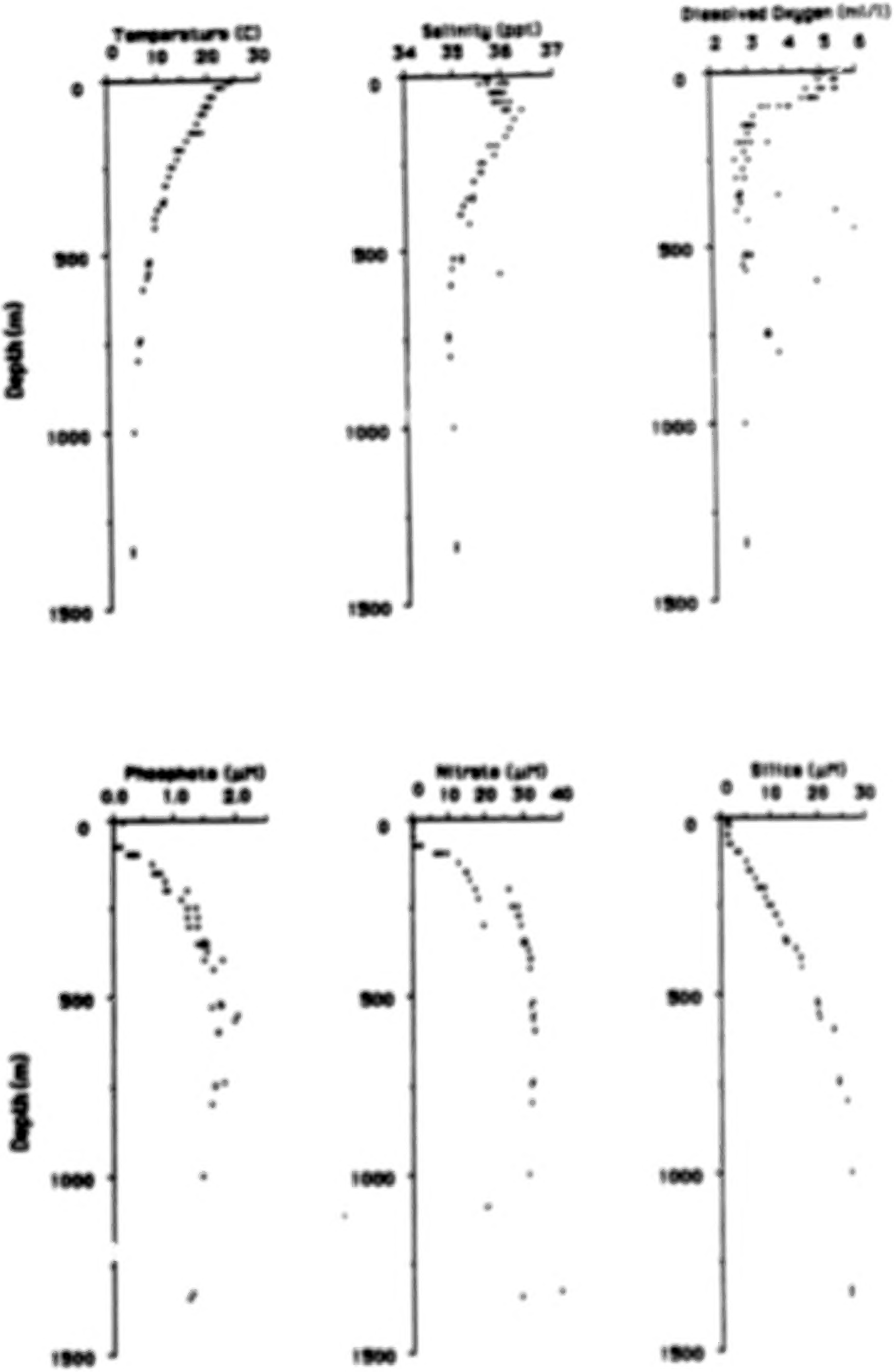
Dissolved Oxygen (ml/l)
2 3 4 5 6
Phosphate (µM)
0 1 2
Nitrate (µM)
0 10 20 30 40
Silica (µM)
0 10 20 30
Depth (m)
0
1000
2000
3000

Cruise V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Salinity (ppt)
34 35 36 37
Dissolved Oxygen (ml/l)
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Phosphate (µM)
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Nitrate (µM)
0 10 20 30 40
Silica (µM)
0 10 20 30
Depth (m)
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500
1000
1500

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ATTACHMENT A1.2: Sediment Data by Cruise and Station

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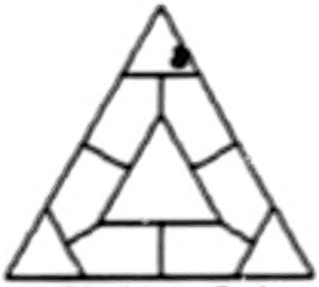

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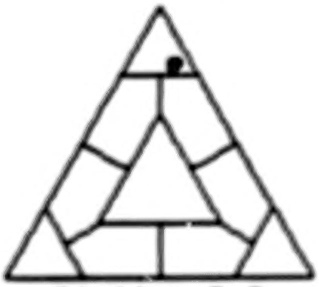

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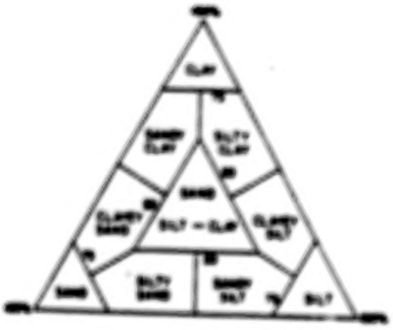

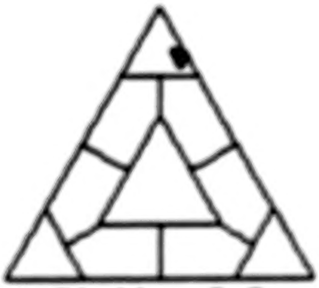

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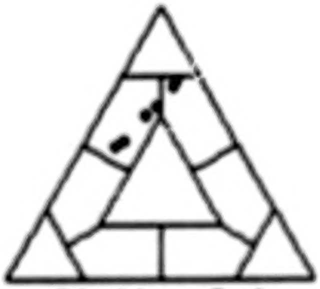

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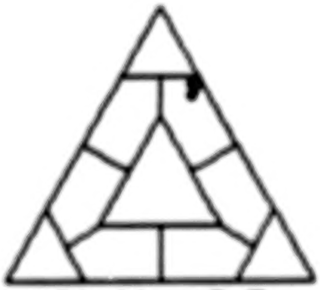
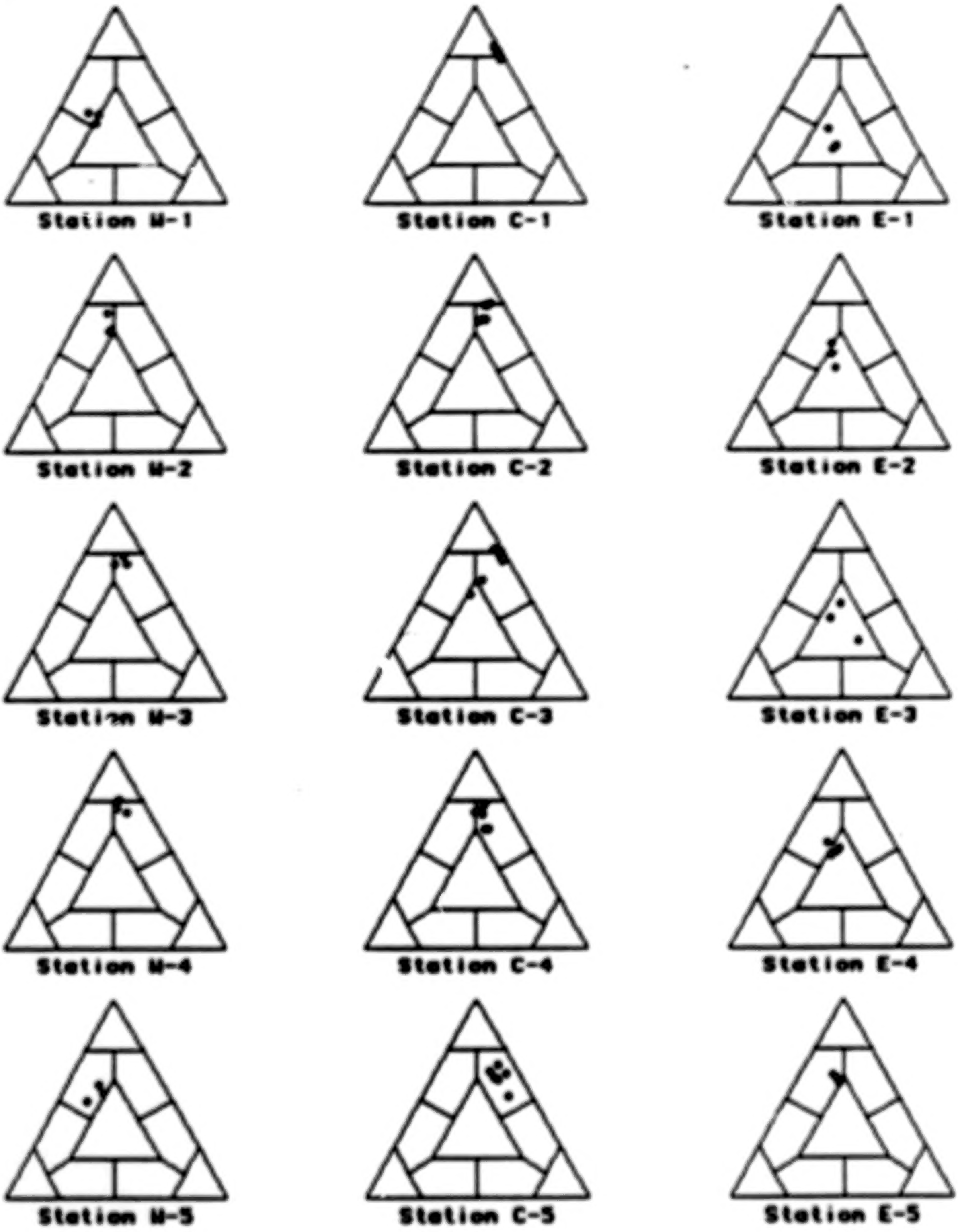


Station C-5

Figure A1.2-1. Sediment triangles Cruise I.



Station W-1 Station C-1 Station E-1

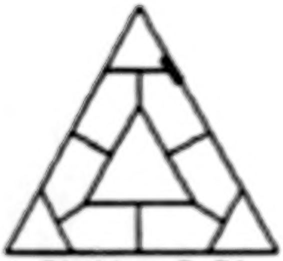
Station W-2 Station C-2 Station E-2

Station W-3 Station C-3 Station E-3

Station W-4 Station C-4 Station E-4

Station W-5 Station C-5 Station E-5

Figure A1.2-2. Sediment triangles Cruise II.



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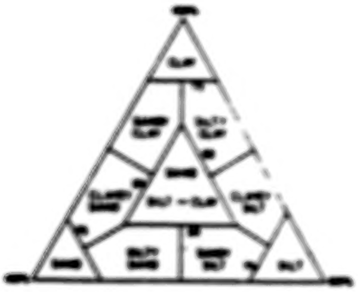

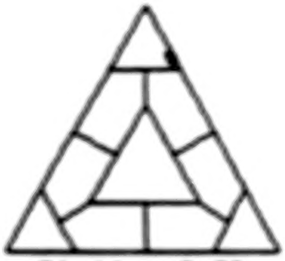

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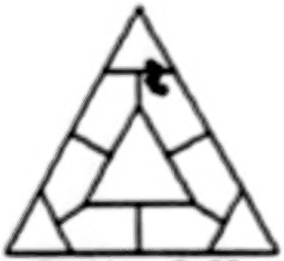

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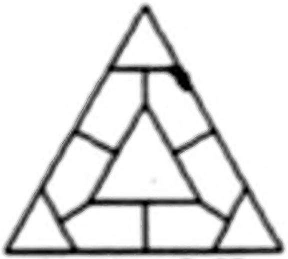

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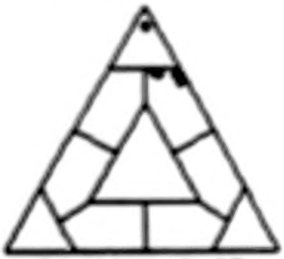

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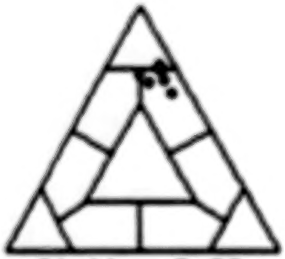

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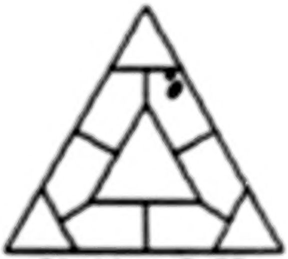

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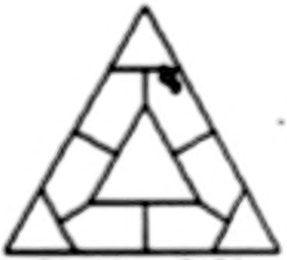

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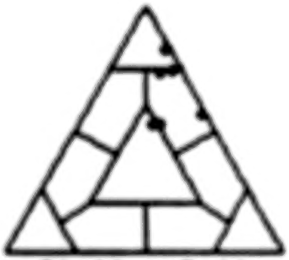

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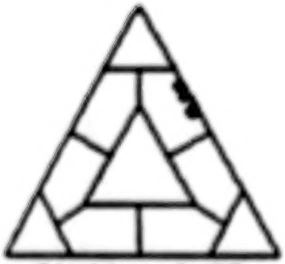

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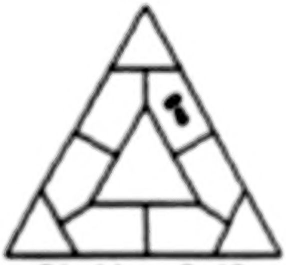
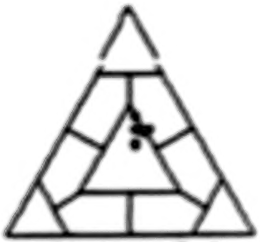


Station C-12

Figure A1.2-3. Sediment trinagles Cruise III.



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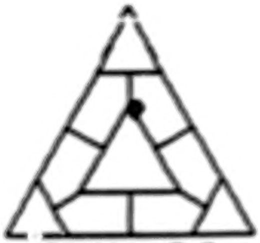

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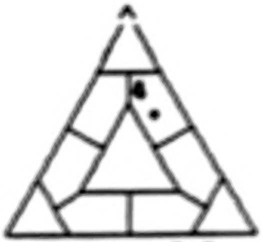

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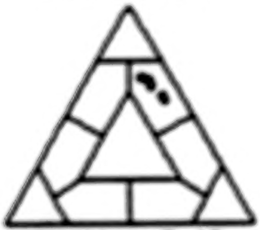

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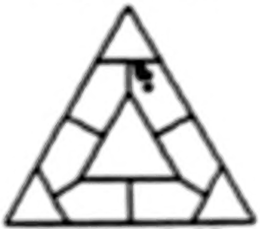

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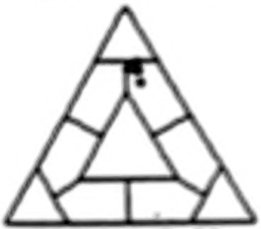

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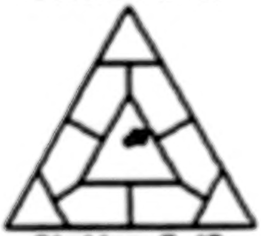

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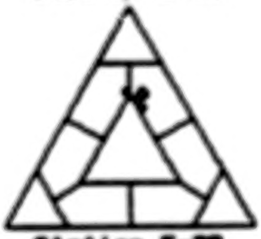

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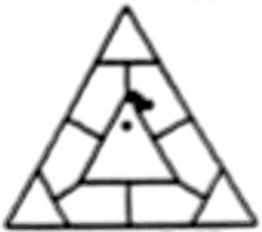

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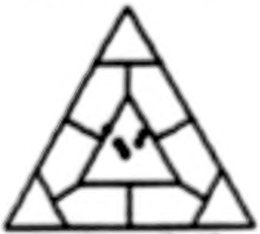

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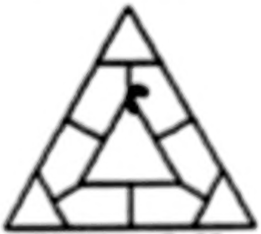

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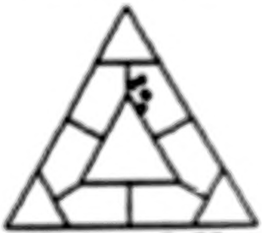

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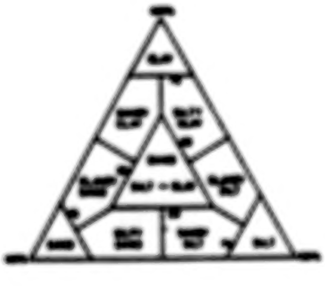

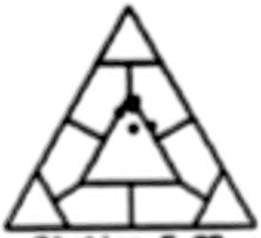

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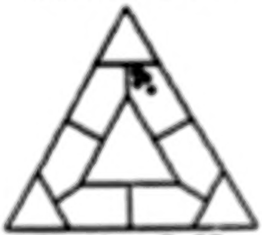

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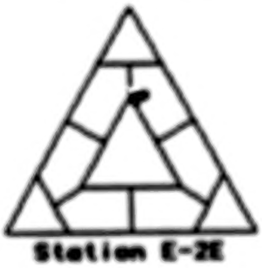

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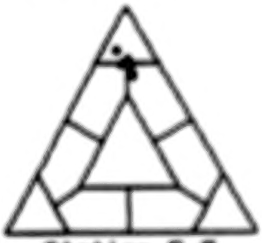

Station E-5

Figure A1.2-4. Sediment triangles Cruise IV.

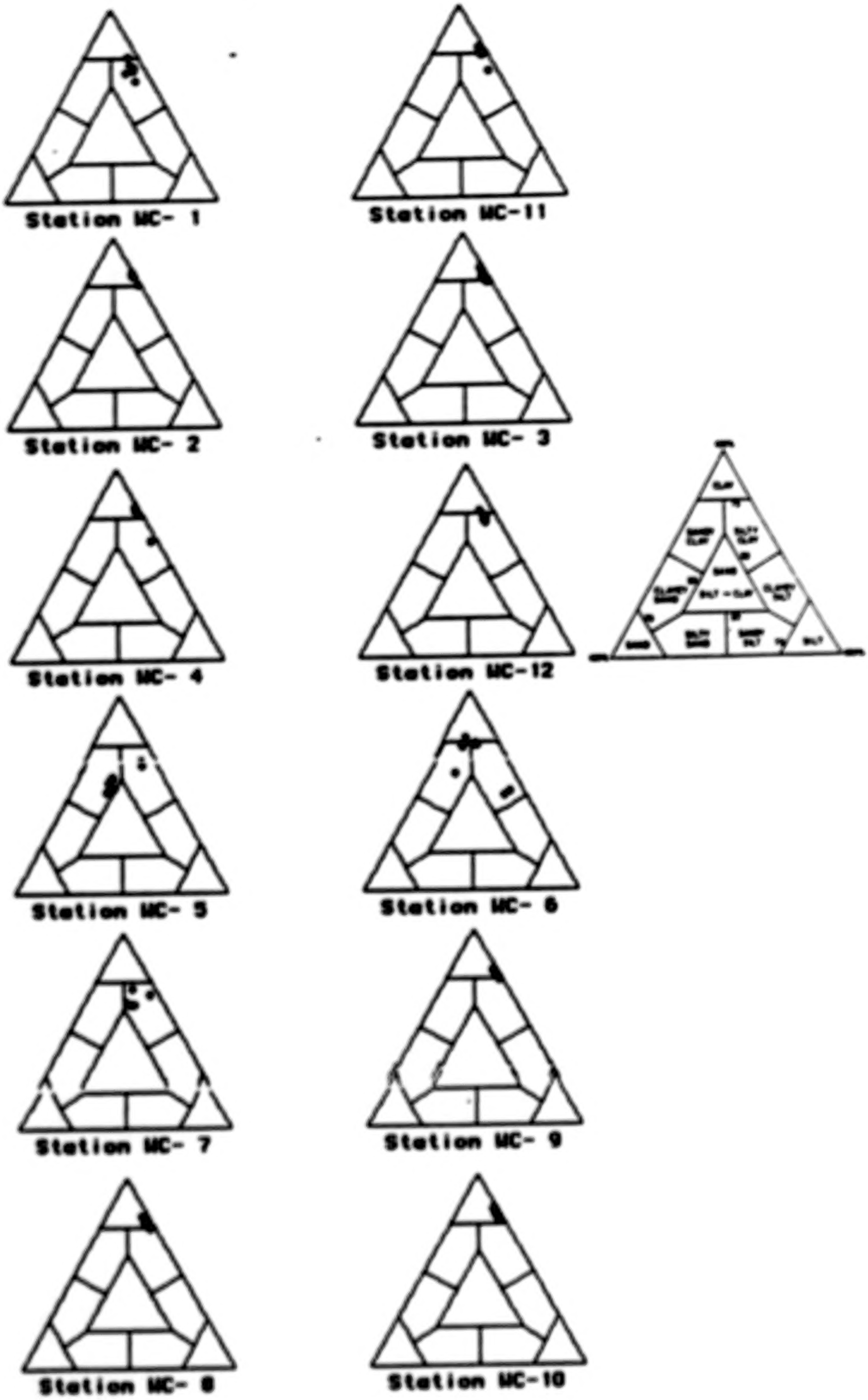

Figure A1.2-5. Sediment triangles Cruise V.

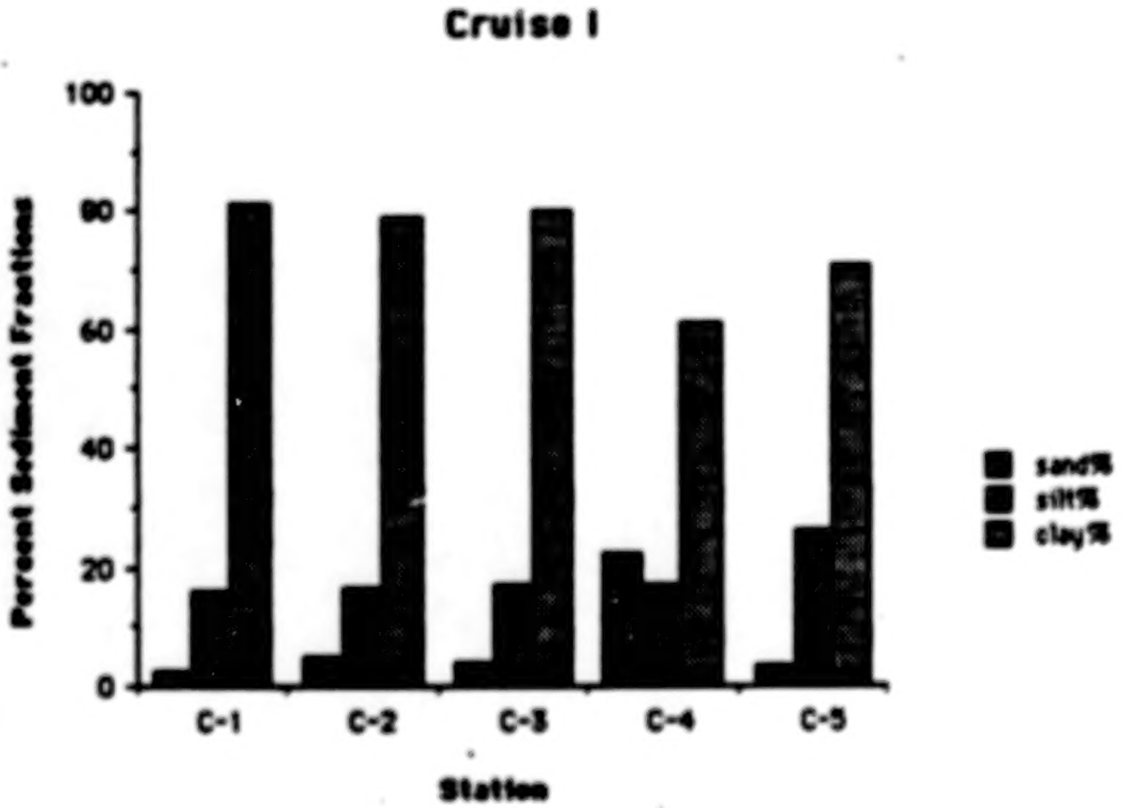
Cruise I
100
80
60
40
20
0
Percent Sediment Fractions
C-1
C-2
C-3
C-4
C-5
Station
sand%
silt%
clay%

Figure A1.2-6.

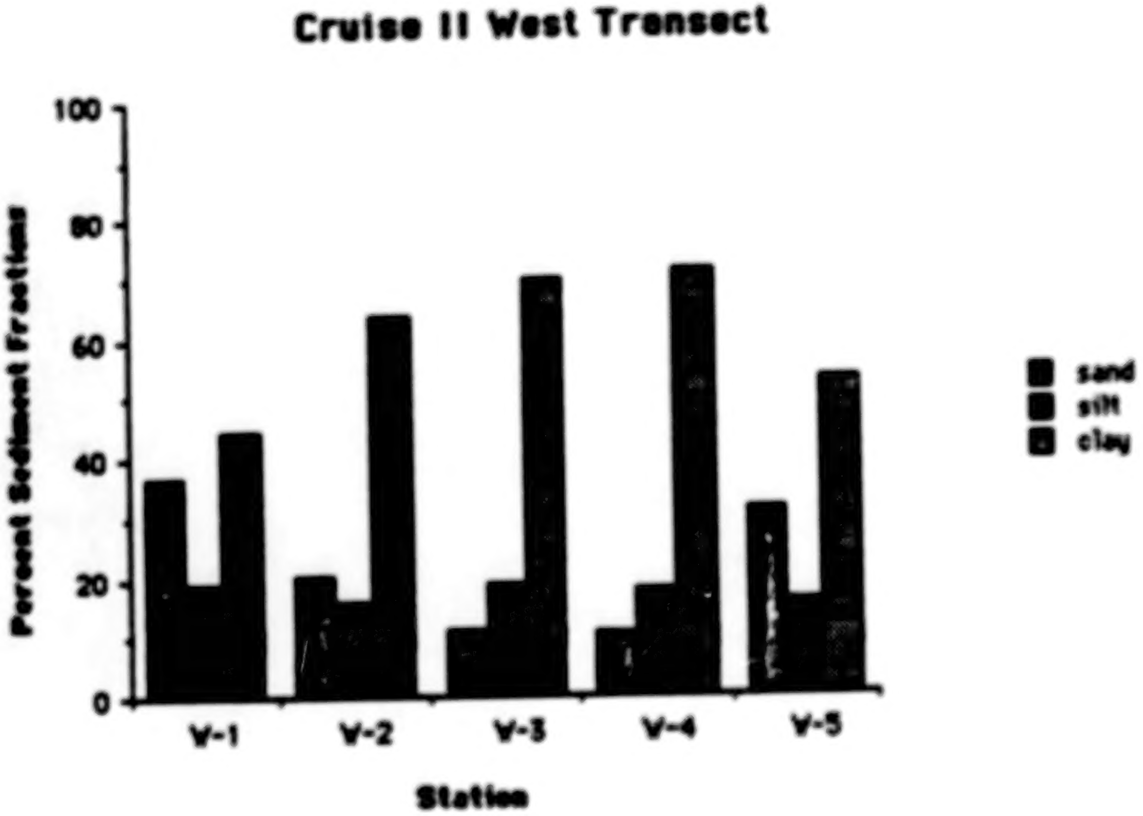
Cruise II West Transect
100
80
60
40
20
0
Percent Sediment Fractions
V-1
V-2
V-3
V-4
V-5
Station
sand
silt
clay

Figure A1.2-7.

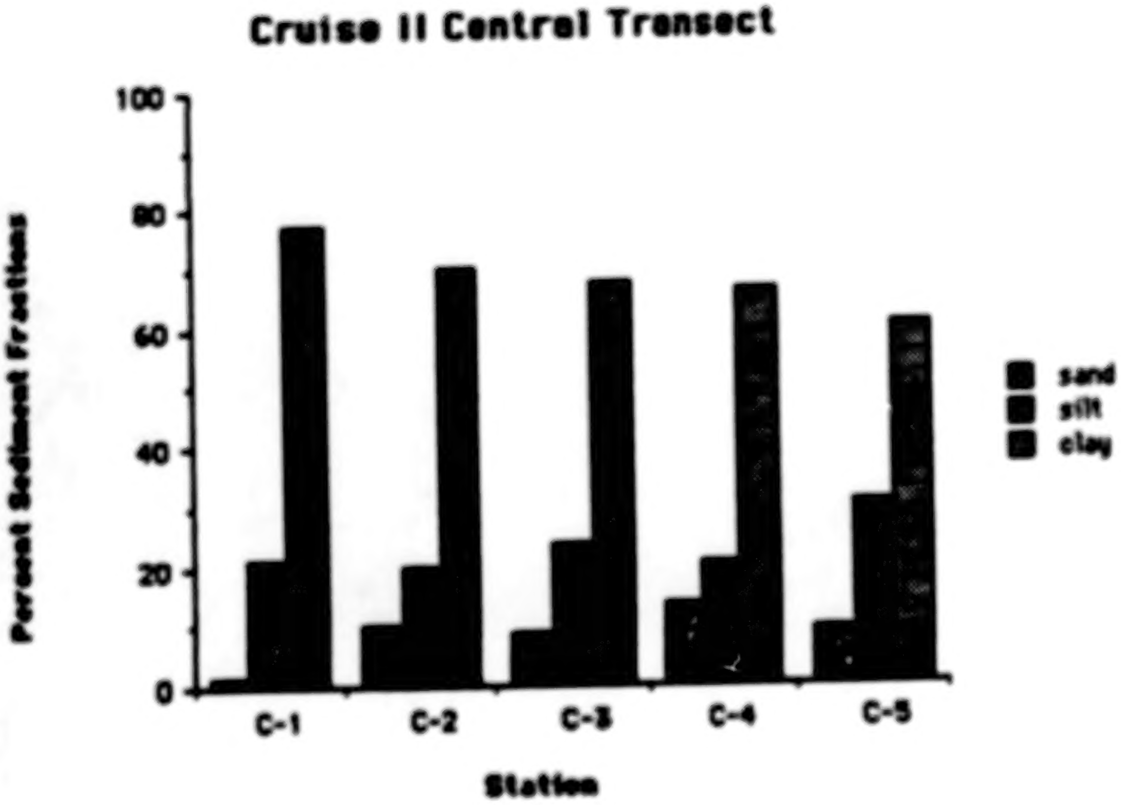
Cruise II Control Transect
100
80
60
40
20
0
Percent Sediment Fractions
C-1
C-2
C-3
C-4
C-5
Station
sand
silt
clay

Figure A1.2-8.

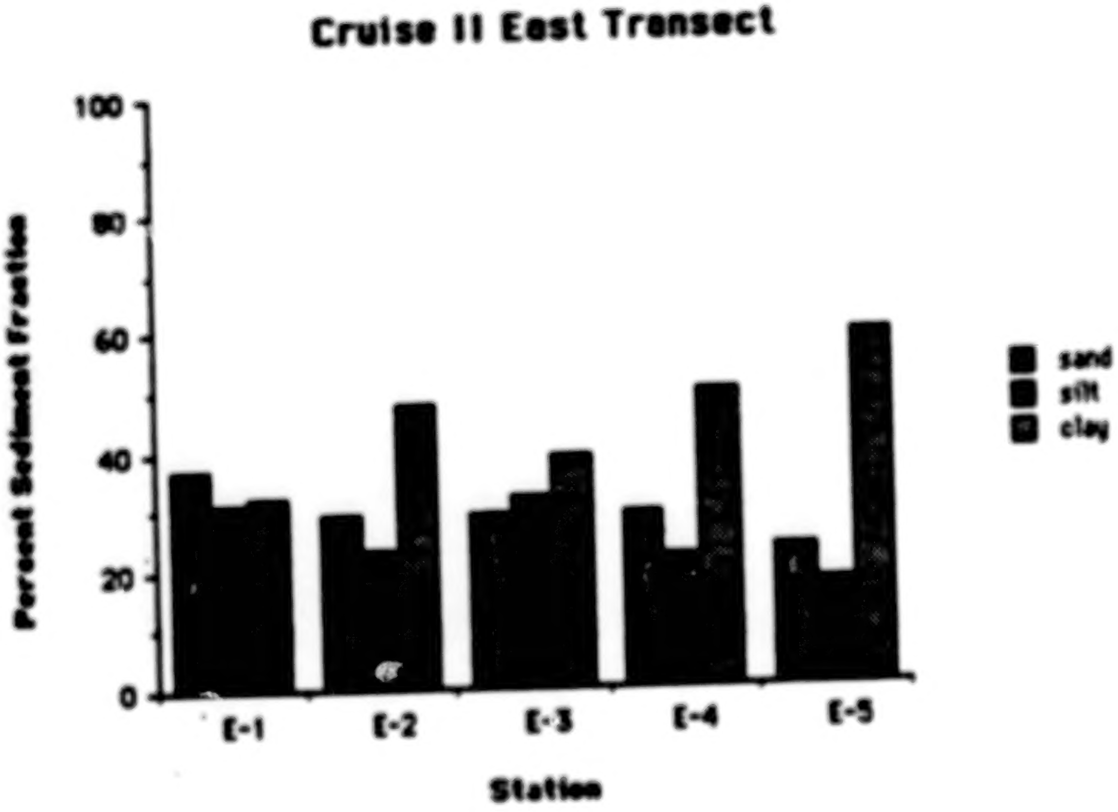
Cruise II East Transect
100
80
60
40
20
0
Percent Sediment Fraction
E-1
E-2
E-3
E-4
E-5
Station
sand
silt
clay

Figure A1.2-9.

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PAGE

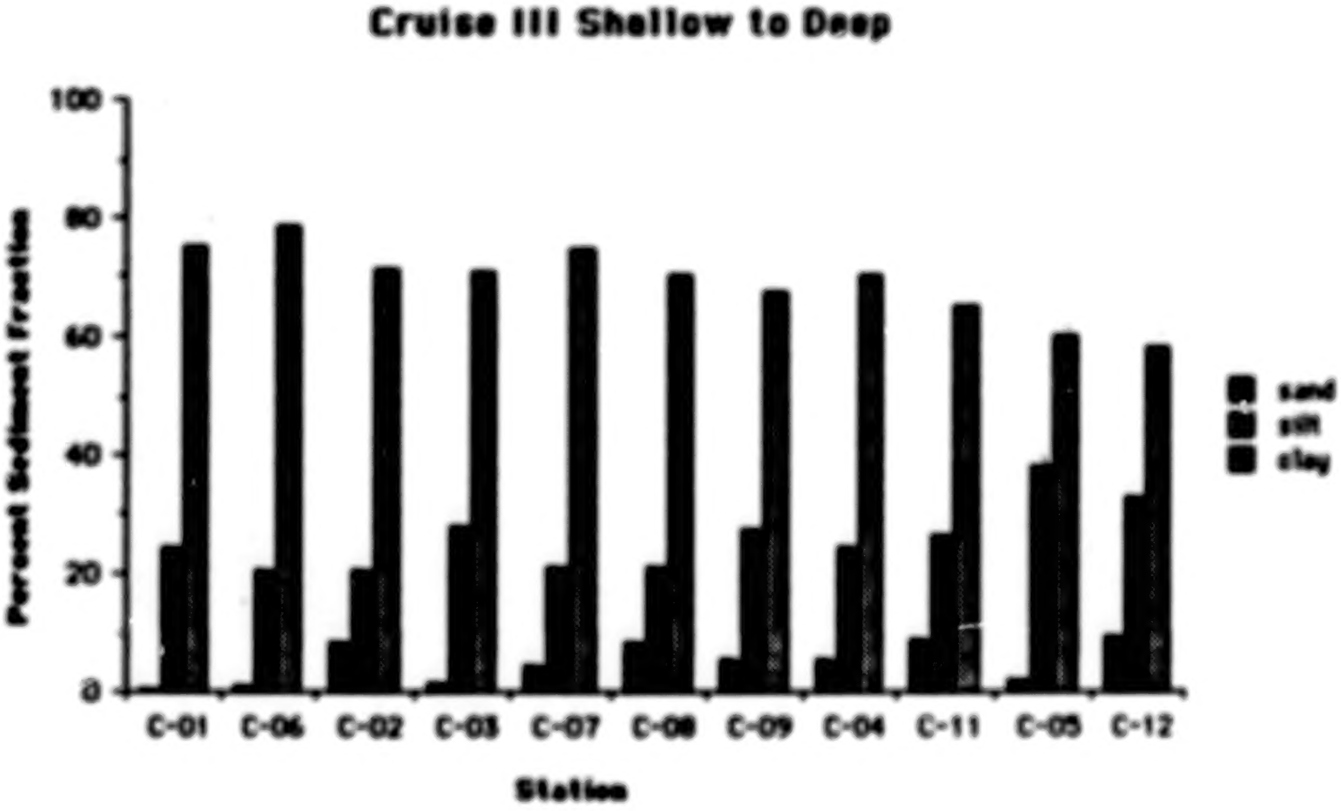

Figure A1.2-10.

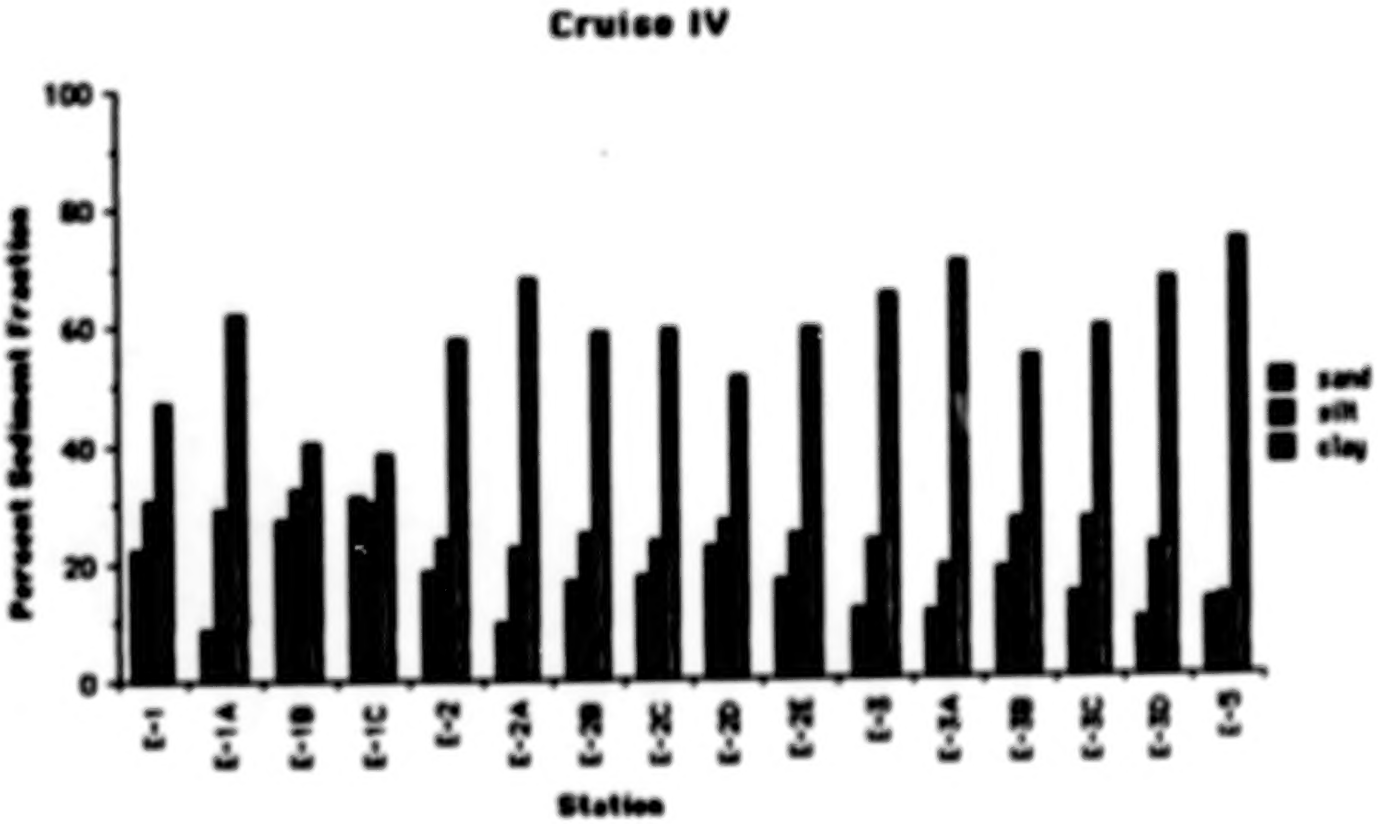

Figure A1.2-11.

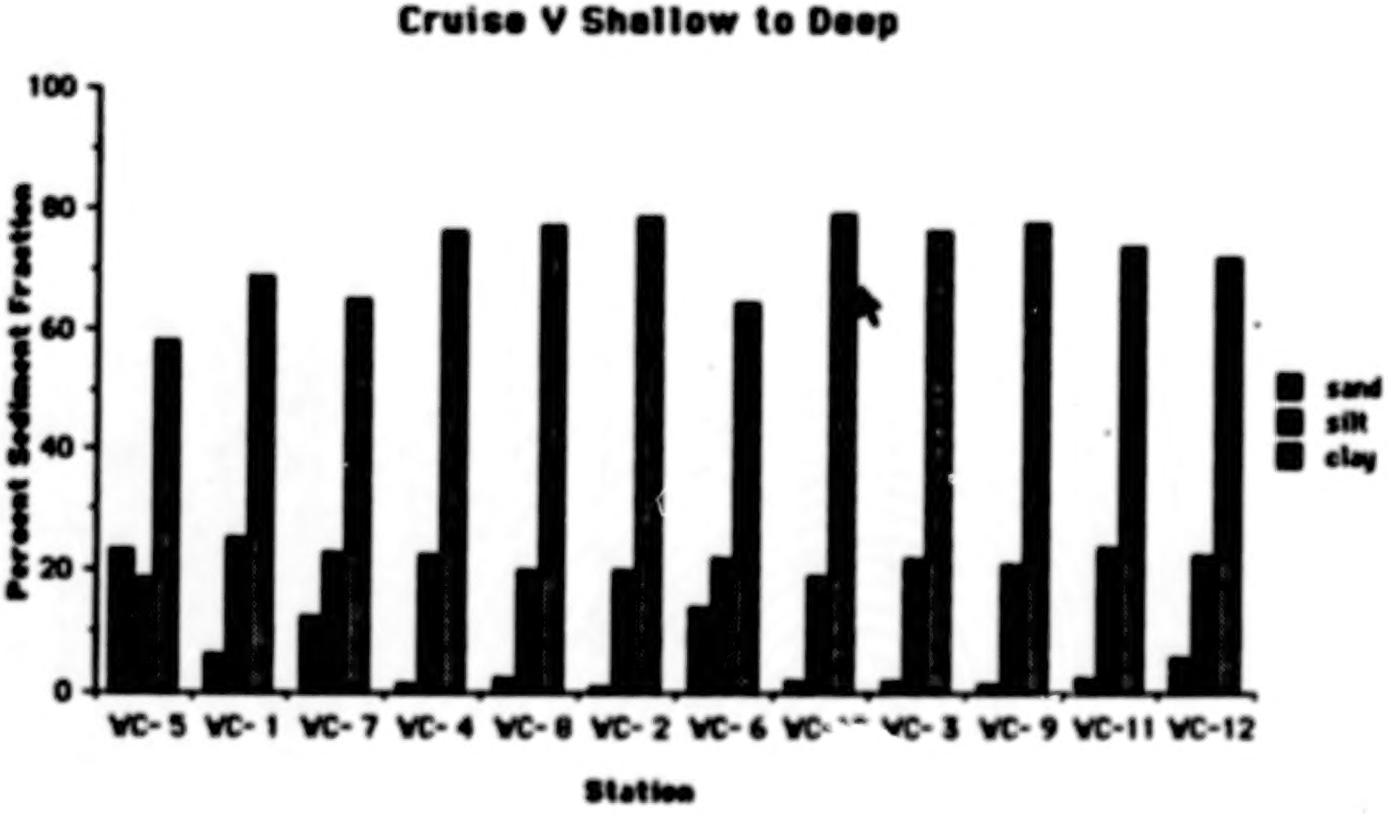

Figure A1.2-12.

ATTACHMENT A2.0: Supportive Data, Section 4.0

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ATTACHMENT A2.1: Summary of Macrofaunal Densities (no/m^2) by Major Taxonomic Group, Cruises I-V

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Cruise I.

TAXON	STATION C 1	C 2	C 3	C 4	C 5	Average
NEMATODA	469	618	343	1175	1500	821
OSTRACODA	70	375	630	231	50	271
COPEPODA	179	310	214	483	252	288
BIVALVIA	138	91	179	240	141	158
TANAIDACEA	108	290	170	193	29	158
BRYOZOA	3	12	21	64	3	21
ISOPODA	580	182	161	146	64	227
AMPHIPODA	190	97	85	53	9	87
APLACOPHORA	56	47	56	26	9	39
NEMERTEA	44	32	35	59	18	38
OPHIUROIDEA	23	12	32	44	26	27
SIPUNCULA	18	6	21	18	0	13
CUMACEA	79	23	18	47	3	34
PORIFERA	0	3	3	12	3	4
SCAPHOPODA	12	15	23	38	23	22
SCYPHOZOA	18	0	0	3	0	4
GASTROPODA	35	9	26	3	3	15
HOLOTHUROIDEA	0	0	0	0	0	0
OLIGOCHAETA	6	0	0	0	26	6
ASCIDIACEA	0	0	9	32	0	8
HYDROZOA	0	0	0	0	0	0
BRACHIOPODA	0	9	0	0	0	2
ARACHNIDA:ACARINA	0	0	0	0	0	0
KINORHYNCHA	3	0	3	9	0	3
ECHINOIDEA	3	0	3	3	15	5
PRIAPULIDA	0	0	3	0	21	5
SCLERACTINEA	0	0	0	0	0	0
DECAPODA	0	6	0	0	0	1
MYSTACOCARIDA	0	0	0	0	0	0
POGONOPHORA/VESTIMENT.	0	0	0	0	0	0
ECHIURA	0	0	0	0	0	0
ACTINIARIA	0	0	0	0	0	0
ALCYONARIA	0	0	0	0	0	0
TURBELLARIA	0	0	0	0	0	0
CRINOIDEA	0	0	0	0	0	0
PYCNOGONIDA	0	0	0	0	0	0
MISC. ANTHOZOA	0	0	0	0	0	0
HEMICHORDATA	0	0	0	0	0	0
ASTEROIDEA	0	0	0	0	0	0
MYSIDACEA	0	0	0	0	0	0
ARCHIANNELIDA	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	3	0	1
CIRRIPEDIA	0	0	0	0	0	0
OSTEICHTHYES	0	0	0	0	0	0
Total	2034	2137	2035	2882	2195	
Without Nematoda	1565	1519	1692	1707	695	

Cruise II Western.

	STATION					
TAXON	W 1	W 2	W 3	W 4	W 5	Average
NEMATODA	667	1396	1235	323	547	834
OSTRACODA	21	204	175	84	126	122
COPEPODA	204	281	456	232	484	331
BIVALVIA	218	112	189	182	84	157
TANAIDACEA	140	147	189	140	112	146
BRYOZOA	84	7	70	14	77	50
ISOPODA	105	211	98	161	28	121
AMPHIPODA	21	63	35	14	7	28
APLACOPHORA	77	14	49	7	21	34
NEMERTEA	49	63	42	21	7	36
OPHIUROIDEA	28	77	133	7	0	49
SIPUNCULA	140	49	0	14	0	41
CUMACEA	21	21	42	7	7	20
PORIFERA	0	7	7	7	84	21
SCAPHOPODA	14	0	28	7	7	11
SCYPHOZOA	0	0	7	0	0	1
GASTROPODA	0	7	21	0	7	7
HOLOTHUROIDEA	0	42	14	0	0	11
OLIGOCHAETA	0	7	0	0	0	1
ASCIDIACEA	0	14	7	0	7	6
HYDROZOA	0	0	0	0	0	0
BRACHIOPODA	0	0	0	7	0	1
ARACHNIDA:ACARINA	0	0	0	0	0	0
KINORHYNCHA	0	0	0	0	0	0
ECHINOIDEA	0	0	7	0	0	1
PRIAPULIDA	0	0	7	0	0	1
SCLERACTINEA	0	0	0	0	0	0
DECAPODA	0	7	0	0	0	1
MYSTACOCARIDA	0	0	0	0	0	0
POGONOPHORA/VESTIMENT	0	0	0	0	0	0
ECHIURA	0	0	0	0	0	0
ACTINIARIA	0	0	0	0	0	0
ALCYONARIA	0	0	0	0	0	0
TURBELLARIA	0	0	0	0	0	0
CRINOIDEA	0	0	0	0	0	0
PYCNOGONIDA	0	0	0	0	0	0
MISC. CRUSTACEA	0	0	0	0	0	0
HEMICHORDATA	0	0	0	0	0	0
ASTEROIDEA	0	0	0	0	0	0
MYSIDACEA	0	0	0	0	0	0
ARCHIANNELIDA	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	0	0	0
OSTEICHTHYES	0	0	0	0	0	0
Total	1789	2729	2811	1227	1605	
Without Nematoda	1122	1333	1576	904	1058	

Cruise II Central.

TAXON	C 1	C 2	C 3	C 4	C 5	Average
NEMATODA	606	940	783	1147	1274	950
OSTRACODA	42	530	319	323	232	289
COPEPODA	166	705	401	607	323	408
BIVALVIA	211	130	283	388	109	224
TANAIDACEA	81	435	337	239	74	233
BRYOZOA	39	49	35	137	28	58
ISOPODA	198	372	161	382	112	245
AMPHIPODA	70	154	154	74	32	97
APLACOPHORA	91	21	53	49	11	45
NEMERTEA	53	39	53	46	25	43
OPHIUROIDEA	67	28	28	32	56	42
SIPUNCULA	11	4	11	25	0	10
CUMACEA	11	60	25	39	18	31
PORIFERA	0	0	4	21	4	6
SCAPHOPODA	0	7	7	14	35	13
SCYPHOZOA	7	0	7	4	14	6
GASTROPODA	42	11	46	35	14	30
HOLOTHUROIDEA	0	4	14	14	4	7
OLIGOCHAETA	0	7	49	4	18	16
ASCIDIACEA	0	0	14	49	0	13
HYDROZOA	14	4	11	11	0	8
BRACHIOPODA	7	11	4	0	25	9
ARACHNIDA:ACARINA	0	0	0	18	0	4
KINORHYNCHA	0	0	0	7	0	1
ECHINOIDEA	0	0	4	14	14	6
PRIAPULIDA	4	0	4	4	28	8
SCLERACTINIA	0	0	0	0	0	0
DECAPODA	4	4	0	0	0	2
MYSTACOCARIDA	0	0	0	0	0	0
POGONOPHORA/VESTIMENT	0	0	0	0	0	0
ECHIURA	0	0	0	0	0	0
ACTINIARIA	4	0	0	7	0	2
ALCYONARIA	0	0	0	0	0	0
TURBELLARIA	0	0	0	0	7	1
CRINOIDEA	0	0	0	7	0	1
PYCNOGONIDA	0	0	0	0	0	0
MISC. ANTHOZOA	0	0	0	0	0	0
HEMICHORDATA	0	0	0	0	0	0
ASTEROIDEA	0	0	0	0	0	0
MYSIDACEA	0	0	0	0	0	0
ARCHIANNELIDA	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	0	0	0
OSTEICHTHYES	0	0	0	0	0	0
Total	1728	3521	3080	3877	2537	
Without Nematoda	1122	2581	2297	2730	1263	

Cruise II Eastern.

TAXON	E 1	E 2	E 3	E 4	E 5	Average
NEMATODA	1891	1886	1786	1124	774	1492
OSTRACODA	211	204	440	304	174	278
COPEPODA	344	285	456	386	303	355
BIVALVIA	372	147	287	257	68	222
TANAIDACEA	63	147	385	282	89	173
BRYOZOA	189	21	91	98	16	82
ISOPODA	49	77	112	173	95	101
AMPHIPODA	0	112	98	46	11	53
APLACOPHORA	182	91	28	25	0	65
NEMERTEA	35	56	21	21	21	31
OPHIUROIDEA	56	21	84	17	5	37
SIPUNCULA	77	35	35	17	21	37
CUMACEA	21	7	77	34	37	35
PORIFERA	0	21	14	25	116	35
SCAPHOPODA	21	0	0	17	0	8
SCYPHOZOA	105	0	42	13	11	34
GASTROPODA	21	0	14	13	21	14
HOLOTHUROIDEA	21	56	35	21	0	27
OLIGOCHAETA	0	56	28	21	63	34
ASCIDIACEA	0	7	28	8	11	11
HYDROZOA	42	0	28	0	0	14
BRACHIOPODA	0	7	0	0	0	1
ARACHNIDA:ACARINA	0	0	14	0	16	6
KINORHYNCHA	35	0	0	0	0	7
ECHINOIDEA	0	7	0	4	5	3
PRIAPULIDA	0	0	14	0	0	3
SCLERACTINIA	0	0	7	0	0	1
DECAPODA	0	7	0	0	0	1
MYSTACOCARIDA	0	0	0	0	0	0
POGONOPHORA/VESTIMENT	0	0	0	0	0	0
ECHIURA	63	0	0	0	0	13
ACTINIARIA	0	0	7	4	0	2
ALCYONARIA	0	0	0	0	0	0
TURBELLARIA	7	0	0	0	0	1
CRINOIDEA	0	0	0	0	0	0
PYCNOGONIDA	0	0	0	0	0	0
MISC. ANTHOZOA	0	0	0	0	0	0
HEMICHORDATA	0	0	0	0	0	0
ASTEROIDEA	0	0	0	0	0	0
MYSIDACEA	0	0	0	0	0	0
ARCHIANNELIDA	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	0	0	0
OSTEICHTHYES	0	0	0	0	0	0
Total	3805	3260	4100	2885	1859	
Without Nematoda	1914	1374	2314	1761	1085	

Cruise III.

TAXON	C 1	C 6	C 2	C 3	C 7	C 8	C 9	C 4	C11	C 5	C12	Average
NEMATODA	225	144	288	228	1568	884	2937	807	463	449	256	750
OSTRACODA	28	42	347	246	393	379	253	168	21	253	77	201
COPEPODA	60	84	63	88	358	309	312	267	119	144	56	169
BIVALVIA	112	109	147	218	396	218	337	214	95	193	91	194
TANAIDACEA	28	46	126	196	512	193	133	116	32	60	35	134
BRYOZOA	0	0	18	18	7	67	140	179	607	42	4	98
ISOPODA	70	98	42	46	232	95	137	154	28	63	56	93
AMPHIPODA	46	91	46	42	232	98	112	28	7	11	0	65
APLACOPHORA	91	25	42	42	211	56	42	32	0	11	0	50
NEMERTEA	21	14	11	18	46	35	7	42	11	7	4	20
OPHIUROIDEA	42	0	4	53	32	46	18	39	4	53	0	26
SIPUNCULA	7	0	4	11	21	21	4	7	4	4	0	8
CUMACEA	18	0	21	18	74	28	39	7	0	7	18	21
PORIFERA	0	0	0	4	7	46	28	25	25	7	25	15
SCAPHOPODA	0	4	4	21	28	18	21	32	28	32	4	17
SCYPHOZOA	7	0	4	0	14	32	32	53	39	7	0	17
GASTROPODA	7	4	7	0	32	14	11	7	0	0	0	7
HOLOTHUROIDEA	0	0	0	4	7	18	11	11	7	18	0	7
OLIGOCHAETA	0	0	0	4	7	0	0	7	0	11	14	4
ASCIDIACEA	0	0	0	7	0	4	21	39	7	4	0	7
HYDROZOA	4	0	7	0	4	0	0	0	0	0	0	1
BRACHIOPODA	0	0	0	0	4	7	4	0	158	25	0	18
ARACHNIDA:ACARINA	0	0	4	0	14	11	0	0	4	0	0	3
KINORHYNCHA	0	0	0	0	4	0	0	7	4	4	0	2
ECHINOIDEA	0	0	4	0	0	0	4	0	0	4	4	1
PRIAPULIDA	0	0	0	0	0	0	0	0	0	7	7	1
SCLERACTINEA	14	0	0	4	0	0	0	7	0	0	0	2
DECAPODA	0	0	0	0	4	0	0	0	0	0	0	0
MYSTACOCARIDA	0	0	42	0	0	0	0	0	0	0	0	4
POGONOPHORA/VESTIMENT	0	0	0	0	18	0	0	0	0	0	0	2

Cruise III (cont'd).

TAXON	STATION C 1	C 6	C 2	C 3	C 7	C 8	C 9	C 4	C11	C 5	C12	Average
ECHIURA	0	0	0	0	0	0	0	0	0	0	0	0
ACTINIARIA	0	0	0	0	0	0	0	4	4	0	0	1
ALCYONARIA	0	0	0	0	0	0	0	0	0	0	0	0
TURBELLARIA	0	0	0	4	0	0	4	0	0	4	0	1
CRINOIDEA	0	0	0	0	0	0	0	0	0	0	0	0
PYCNOGONIDA	0	0	0	0	0	0	0	4	0	0	0	0
MISC. ANTHOZOA	0	0	0	0	0	0	0	0	0	0	0	0
HEMICHORDATA	0	0	0	0	0	0	0	4	0	0	0	0
ASTEROIDEA	4	0	0	0	4	0	0	0	0	0	0	1
MYSIDACEA	0	0	0	0	0	0	0	4	0	0	0	0
ARCHIANNELIDA	0	0	0	0	0	0	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	0	0	0	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	4	0	0	0	0	0	0	0	0
OSTEICHTHYES	4	0	0	0	0	0	0	0	0	0	0	0
Total	788	661	1231	1276	4229	2579	4611	2264	1667	1420	651	
Without Nematoda	563	517	943	1048	2661	1695	1674	1457	1204	971	395	

Cruise IV.

TAXON	E1B	E1C	E1A	E1	E2B	E2	E2C	E2A	E2D	E2E	E3A	E3B	E3C	E3D	E3	E5	Average
	STATION																
NEMATODA	1400	1298	1326	1561	2011	1558	1639	1119	2098	2246	1428	1604	2172	1144	1228	488	1520
OSTRACODA	172	267	102	270	585	389	326	1084	411	512	484	267	428	435	267	144	379
COPEPODA	98	175	105	193	344	225	182	151	196	256	277	214	281	182	161	144	199
BIVALVIA	36[illegible]	484	323	421	260	211	225	172	218	396	354	235	372	400	179	133	296
TANAIDACEA	1[illegible]6	172	81	165	439	393	393	519	491	456	368	295	509	425	298	74	325
BRYOZOA	[illegible]26	393	95	379	1168	653	891	105	161	747	319	519	288	123	151	74	412
ISOPODA	35	56	77	25	246	189	179	172	144	214	91	151	151	119	109	81	127
AMPHIPODA	39	39	49	18	88	91	70	137	91	77	126	119	158	91	151	21	85
APLACOPHORA	102	67	74	130	105	130	77	109	112	133	102	35	77	84	63	4	88
NEMERTEA	60	70	56	56	55	70	70	53	60	56	42	70	81	60	42	7	57
OPHIUROIDEA	39	70	56	74	60	28	25	28	21	46	70	77	95	91	46	0	52
SIPUNCULA	161	175	144	182	60	67	49	46	70	123	28	46	39	63	42	4	81
CUMACEA	49	81	18	11	60	70	18	39	49	53	49	56	119	35	32	32	48
PORIFERA	46	32	4	28	70	74	56	4	63	60	46	28	81	70	32	137	52
SCAPHOPODA	60	63	56	105	28	18	28	0	21	28	46	18	32	56	11	4	36
SCYPHOZOA	116	53	182	126	32	4	7	4	25	21	14	11	0	11	11	7	39
GASTROPODA	14	14	11	21	32	7	4	18	25	42	35	25	28	49	14	7	22
HOLOTHUROIDEA	18	14	7	7	42	60	63	28	84	56	21	46	46	42	49	14	37
OLIGOCHAETA	11	21	0	0	53	53	63	4	35	0	39	42	21	39	35	21	27
ASCIDIACEA	0	0	0	0	11	0	11	11	4	18	25	11	32	25	21	11	11
HYDROZOA	4	7	98	7	4	4	7	0	18	4	0	4	7	4	11	7	12
BRACHIOPODA	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	0	0
ARACHNIDA:ACARINA	0	11	0	0	4	7	0	0	0	4	4	14	4	7	14	4	5
KINORHYNCHA	28	49	4	60	0	0	0	0	0	0	0	0	7	0	4	0	10
ECHINOIDEA	0	4	0	4	4	4	4	0	0	4	4	11	0	4	4	4	3
PRIAPULIDA	7	0	7	4	0	0	0	4	0	0	0	0	0	0	0	0	1
SCLERACTINEA	0	0	0	0	0	4	4	0	0	0	4	0	0	0	0	0	1
DECAPODA	4	4	7	4	0	4	7	4	0	11	0	0	0	0	0	0	3
MYSTACOCARIDA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POGO./VEST.	0	0	0	0	0	0	0	0	0	4	0	0	4	0	4	0	1

Cruise IV (cont'd).

	STATION																
TAXON	E1B	E1C	E1A	E1	E2B	E2	E2C	E2A	E2D	E2E	E3A	E3B	E3C	E3D	E3	E5	Average
ECHIURA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACTINIARIA	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
ALCYONARIA	0	0	0	0	0	0	4	7	4	0	4	0	0	4	7	0	2
TURBELLARIA	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CRINOIDEA	0	0	0	0	0	0	0	0	0	4	0	4	0	0	7	0	1
PYCNOGONIDA	0	0	0	0	0	7	4	0	0	0	4	0	4	0	0	0	1
MISC. ANTHOZOA	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0
HEMICHORDATA	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
ASTEROIDEA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MYSIDACEA	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARCHIANNELIDA	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OSTEICHTHYES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	3470	3619	2886	3855	5682	4320	4406	3818	4401	5575	3991	3902	5044	3563	2997	1422	
Without Nematoda	2070	2312	1560	2294	3671	2782	2767	2699	2303	3329	2563	2298	2872	2419	1769	934	

Cruise V.

TAXON	STATION												
	WC1	WC5	WC7	WC8	WC4	WC2	WC6	WCA	WC9	WC3	WCB	WCC	Average
NEMATODA	986	1758	1200	839	632	407	2053	533	681	589	919	677	940
OSTRACODA	67	228	182	751	396	372	589	393	705	491	263	277	393
COPEPODA	140	147	109	140	316	214	246	151	133	109	200	112	168
BIVALVIA	305	326	144	246	196	316	270	144	218	211	172	214	230
TANAIDACEA	77	221	186	365	333	421	347	126	351	295	144	137	250
BRYOZOA	70	544	239	49	56	263	319	133	133	263	98	81	187
ISOPODA	88	39	109	207	207	147	221	56	123	81	154	147	132
AMPHIPODA	46	186	84	165	95	102	95	84	130	98	63	60	101
APLACOPHORA	39	11	4	42	42	46	77	35	70	28	35	14	37
NEMERTEA	28	158	25	46	32	14	42	18	32	25	18	35	39
OPHIUROIDEA	32	32	4	4	25	18	63	18	42	35	74	63	34
SIPUNCULA	35	46	18	21	7	28	70	21	25	4	7	14	25
CUMACEA	11	130	14	18	28	4	63	11	21	14	7	0	27
PORIFERA	25	63	11	0	14	39	32	4	25	14	28	21	23
SCAPHOPODA	28	53	46	11	28	35	28	18	21	25	18	21	28
SCYPHOZOA	49	53	14	7	18	7	0	14	21	4	4	14	17
GASTROPODA	11	70	11	28	7	32	21	11	18	4	14	21	21
HOLOTHUROIDEA	0	4	0	0	18	0	0	0	4	14	14	18	6
OLIGOCHAETA	7	70	28	7	7	0	32	0	0	0	7	11	14
ASCIDIACEA	0	0	0	0	0	4	7	11	18	14	11	0	5
HYDROZOA	14	18	39	0	4	11	4	0	0	4	0	0	8
BRACHIOPODA	0	0	7	0	0	4	0	0	0	0	0	0	1
ARACHNIDA:ACARINA	0	46	4	4	4	0	11	14	0	0	0	0	7
KINORHYNCHA	0	0	0	0	0	0	0	0	0	0	0	0	0
ECHINOIDEA	0	4	0	0	7	7	0	4	0	7	7	4	3
PRIAPULIDA	0	0	0	0	0	0	4	0	0	0	0	0	0
SCLERACTINEA	0	63	0	0	0	7	4	0	4	0	0	0	6
DECAPODA	0	4	7	7	4	0	0	0	0	0	0	0	2
MYSTACOCARIDA	0	0	0	0	0	0	0	0	0	0	0	0	0
POGONOPHORA/VESTIMENT	0	0	0	0	0	0	0	4	0	0	7	0	1

Cruise V (cont'd).

	STATION												
TAXON	WC1	WC5	WC7	WC8	WC4	WC2	WC6	WCA	WC9	WC3	WCB	WCC	Average
ECHIURA	0	0	0	0	0	0	0	0	0	0	0	0	0
ACTINIARIA	0	0	0	0	0	0	0	0	0	0	0	0	0
ALCYONARIA	0	0	0	0	0	0	0	0	0	0	0	0	0
TURBELLARIA	0	0	0	0	0	0	4	0	0	0	0	0	0
CRINOIDEA	0	0	0	0	0	0	0	0	0	0	0	0	0
PYCNOGONIDA	0	4	0	0	0	0	0	0	0	0	0	0	0
MISC. ANTHOZOA	0	0	0	0	0	0	0	0	0	0	0	7	1
HEMICHORDATA	0	7	0	0	0	0	0	0	0	0	0	0	1
ASTEROIDEA	0	0	0	0	0	0	0	0	0	0	0	0	0
MYSIDACEA	0	0	0	0	0	0	0	0	0	0	0	0	0
ARCHIANNELIDA	0	0	0	0	0	0	0	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	0	0	0	0	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	0	0	0	0	0	0	0	0	0	0
OSTEICHTHYES	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2058	4285	2485	2957	2476	2498	4602	1803	2775	2329	2264	1948	
Without Nematoda	1072	2527	1285	2116	1840	2091	2549	1270	2094	1740	1345	1271	

ATTACHMENT A2.2: Summary of Macrofaunal Taxa by Station and Cruise

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Cruise I.

TAXON	STATION C 1	C 2	C 3	C 4	C 5	Total
TANAIDACEA	13	25	27	28	6	65
ISOPODA	9	16	25	27	8	58
BRYOZOA	1	2	5	8	1	11
CUMACEA	14	7	6	10	1	27
AMPHIPODA	21	12	16	9	2	36
BIVALVIA	14	8	16	17	9	35
GASTROPODA	8	2	6	1	1	15
PORIFERA	0	1	1	2	1	5
SIPUNCULA	6	2	5	4	0	14
OSTRACODA	4	5	4	3	1	10
NEMERTEA	6	4	4	4	3	8
ASCIDIACEA	0	0	1	2	0	2
OPHIUROIDEA	5	4	4	7	3	16
HYDROZOA	0	0	0	0	0	0
DECAPODA	0	2	0	0	0	2
HOLOTHUROIDEA	0	0	0	0	0	0
SCAPHOPODA	2	4	3	6	4	8
OLIGOCHAETA	2	0	0	0	2	4
ECHINOIDEA	1	0	1	1	2	2
SCLERACTINEA	0	0	0	0	0	0
ACTINIARIA	0	0	0	0	0	0
KINORHYNCHA	1	0	1	1	0	1
PYCNOGONIDA	0	0	0	0	0	0
MISC. ANTHOZOA	0	0	0	0	0	0
ALCYONARIA	0	0	0	0	0	0
ASTEROIDEA	0	0	0	0	0	0
BRACHIOPODA	0	1	0	0	0	1
COPEPODA	1	1	1	1	1	1
CRINOIDEA	0	0	0	0	0	0
APLACOPHORA	1	1	1	1	1	1
ARACHNIDA/ACARINA	0	0	0	0	0	0
ARCHIANNELIDA	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	1	0	1
CIRRIPEDIA	0	0	0	0	0	0
ECHIURA	0	0	0	0	0	0
HEMICHORDATA	0	0	0	0	0	0
MYSIDACEA	0	0	0	0	0	0
MYSTACOCARIDA	0	0	0	0	0	0
NEMATODA	1	1	1	1	1	1
OSTEICHTHYES	0	0	0	0	0	0
POGONOPHORA/VESTIMENT.	0	0	0	0	0	0
PRIAPULIDA	0	0	1	0	1	1
SCYPHOZOA	1	0	0	1	0	1
TURBELLARIA	0	0	0	0	0	0
Total	111	98	129	135	48	

Cruise II Western.

TAXON	STATION W 1	W 2	W 3	W 4	W 5	Total
TANAIDACEA	11	15	20	12	8	50
ISOPODA	3	14	8	17	4	35
BRYOZOA	8	1	5	2	8	21
CUMACEA	3	3	5	1	1	10
AMPHIPODA	3	4	5	2	1	11
BIVALVIA	8	8	12	15	6	24
GASTROPODA	0	1	2	0	1	3
PORIFERA	0	1	1	1	3	6
SIPUNCULA	7	5	0	2	0	9
OSTRACODA	2	6	4	3	1	6
NEMERTEA	3	3	2	3	1	6
ASCIDIACEA	0	1	1	0	1	2
OPHIUROIDEA	1	1	1	1	0	1
HYDROZOA	0	0	0	0	0	0
DECAPODA	0	1	0	0	0	1
HOLOTHUROIDEA	0	2	1	0	0	3
SCAPHOPODA	1	0	2	1	1	4
OLIGOCHAETA	0	1	0	0	0	1
ECHINOIDEA	0	0	1	0	0	1
SCLERACTINEA	0	0	0	0	0	0
ACTINIARIA	0	0	0	0	0	0
KINORHYNCHA	0	0	0	0	0	0
PYCNOGONIDA	0	0	0	0	0	0
MISC. ANTHOZOA	0	0	0	0	0	0
ALCYONARIA	0	0	0	0	0	0
ASTEROIDEA	0	0	0	0	0	0
BRACHIOPODA	0	0	0	1	0	1
COPEPODA	1	1	1	1	1	1
CRINOIDEA	0	0	0	0	0	0
APLACOPHORA	1	1	1	1	1	1
ARACHNIDA/ACARINA	0	0	0	0	0	0
ARCHIANNELIDA	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	0	0	0
ECHIURA	0	0	0	0	0	0
HEMICHORDATA	0	0	0	0	0	0
MYSIDACEA	0	0	0	0	0	0
MYSTACOCARIDA	0	0	0	0	0	0
NEMATODA	1	1	1	1	1	1
OSTEICHTHYES	0	0	0	0	0	0
POGONOPHORA/VESTIMENT.	0	0	0	0	0	0
PRIAPULIDA	0	0	1	0	0	1
SCYPHOZOA	0	0	1	0	0	1
TURBELLARIA	0	0	0	0	0	0
Total	53	70	75	64	39	

Cruise II Central.

TAXON	STATION C1	C2	C3	C4	C5	Total
TANAIDACEA	8	31	32	31	12	66
ISOPODA	5	32	18	32	8	62
BRYOZOA	8	9	9	14	2	34
CUMACEA	3	10	6	9	3	23
AMPHIPODA	10	16	16	12	3	32
BIVALVIA	9	13	16	17	13	36
GASTROPODA	4	2	2	1	1	5
PORIFERA	0	0	1	4	1	6
SIPUNCULA	2	1	2	3	0	8
OSTRACODA	1	8	7	3	1	9
NEMERTEA	7	3	5	5	3	8
ASCIDIACEA	0	0	1	3	0	3
OPHIUROIDEA	1	1	1	1	1	1
HYDROZOA	3	1	2	1	0	6
DECAPODA	1	1	0	0	0	2
HOLOTHUROIDEA	0	1	2	3	1	3
SCAPHOPODA	0	1	1	3	2	4
OLIGOCHAETA	0	1	1	1	2	3
ECHINOIDEA	0	0	1	1	1	1
SCLERACTINEA	0	0	0	0	0	0
ACTINIARIA	1	0	0	1	0	2
KINORHYNCHA	0	0	0	1	0	1
PYCNOGONIDA	0	0	0	0	0	0
MISC. ANTHOZOA	0	0	0	0	0	0
ALCYONARIA	0	0	0	0	0	0
ASTEROIDEA	0	0	0	0	0	0
BRACHIOPODA	1	1	1	0	1	1
COPEPODA	1	1	1	1	1	1
CRINOIDEA	0	0	0	1	0	1
APLACOPHORA	1	1	1	1	1	1
ARACHNIDA/ACARINA	0	0	0	1	0	1
ARCHIANNELIDA	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	0	0	0
ECHIURA	0	0	0	0	0	0
HEMICHORDATA	0	0	0	0	0	0
MYSIDACEA	0	0	0	0	0	0
MYSTACOCARIDA	0	0	0	0	0	0
NEMATODA	1	1	1	1	1	1
OSTEICHTHYES	0	0	0	0	0	0
POGONOPHORA/VESTIMEN	0	0	0	0	0	0
PRIAPULIDA	1	0	1	1	1	1
SCYPHOZOA	1	0	1	1	1	1
TURBELLARIA	0	0	0	0	1	1
Total	69	135	129	153	61	

Cruise II Eastern.

TAXON	STATION E 1	E 2	E 3	E 4	E 5	Total
TANAIDACEA	8	18	27	27	10	61
ISOPODA	6	8	9	24	11	45
BRYOZOA	7	2	6	7	3	18
CUMACEA	3	1	9	7	4	18
AMPHIPODA	0	9	10	9	2	22
BIVALVIA	12	11	12	17	4	27
GASTROPODA	3	0	2	2	1	5
PORIFERA	0	3	1	4	5	10
SIPUNCULA	5	3	1	2	3	11
OSTRACODA	4	6	5	4	1	11
NEMERTEA	4	3	3	2	3	9
ASCIDIACEA	0	1	2	1	2	4
OPHIUROIDEA	1	1	1	1	1	1
HYDROZOA	1	0	1	0	0	2
DECAPODA	0	1	0	0	0	1
HOLOTHUROIDEA	1	2	2	3	0	4
SCAPHOPODA	1	0	0	2	0	3
OLIGOCHAETA	0	3	3	2	2	5
ECHINOIDEA	0	1	0	1	1	1
SCLERACTINEA	0	0	1	0	0	1
ACTINIARIA	0	0	1	1	0	2
KINORHYNCHA	1	0	0	0	0	1
PYCNOGONIDA	0	0	0	0	0	0
MISC. ANTHOZOA	0	0	0	0	0	0
ALCYONARIA	0	0	0	0	0	0
ASTEROIDEA	0	0	0	0	0	0
BRACHIOPODA	0	1	0	0	0	1
COPEPODA	1	1	1	1	1	1
CRINOIDEA	0	0	0	0	0	0
APLACOPHORA	1	1	1	1	0	1
ARACHNIDA:ACARINA	0	0	1	0	1	1
ARCHIANNELIDA	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	0	0	0
ECHIURA	1	0	0	0	0	1
HEMICHORDATA	0	0	0	0	0	0
MYSIDACEA	0	0	0	0	0	0
MYSTACOCARIDA	0	0	0	0	0	0
NEMATODA	1	1	1	1	1	1
OSTEICHTHYES	0	0	0	0	0	0
POGONOPHORA/VESTIMENT.	0	0	0	0	0	0
PRIAPULIDA	0	0	1	0	0	1
SCYPHOZOA	1	0	1	1	1	1
TURBELLARIA	1	0	0	0	0	1
Total	63	77	102	120	57	

Cruise III.

TAXON	C 1	C 6	C 2	C 3	C 7	C 8	C 9	C 4	C11	C 5	C12	Total
	STATION											
TANAIDACEA	5	6	17	18	32	23	23	24	6	12	6	78
ISOPODA	2	5	10	10	29	19	21	15	6	10	8	65
BRYOZOA	0	0	3	2	1	5	5	10	8	4	1	20
CUMACEA	2	0	5	3	9	7	8	2	0	2	3	30
AMPHIPODA	6	6	7	6	10	12	10	5	2	2	0	25
BIVALVIA	10	9	11	12	16	18	18	13	11	8	7	42
GASTROPODA	2	1	2	0	4	4	3	2	0	0	0	13
PORIFERA	0	0	0	1	2	8	5	7	4	2	5	21
SIPUNCULA	2	0	1	3	3	4	1	2	1	1	0	10
OSTRACODA	1	5	5	5	5	3	2	2	1	2	1	10
NEMERTEA	5	3	3	3	6	5	1	6	1	2	1	12
ASCIDIACEA	0	0	0	1	0	1	5	4	2	1	0	8
OPHIUROIDEA	1	0	1	1	1	1	1	1	1	1	0	1
HYDROZOA	1	0	1	0	1	0	0	0	0	0	0	3
DECAPODA	0	0	0	0	1	0	0	0	0	0	0	1
HOLOTHUROIDEA	0	0	0	1	1	1	1	3	2	2	0	8
SCAPHOPODA	0	1	1	3	1	3	4	1	1	1	1	6
OLIGOCHAETA	0	0	0	1	2	0	0	1	0	1	2	3
ECHINOIDEA	0	0	1	0	0	0	1	0	0	1	1	1
SCLERACTINEA	2	0	0	1	0	0	0	2	0	0	0	4
ACTINIARIA	0	0	0	0	0	0	0	1	1	0	0	1
KINORHYNCHA	0	0	0	0	1	0	0	1	1	1	0	1
PYCNOGONIDA	0	0	0	0	0	0	0	1	0	0	0	1
MISC. ANTHOZOA	0	0	0	0	0	0	0	0	0	0	0	0
ALCYONARIA	0	0	0	0	0	0	0	0	0	0	0	0
ASTEROIDEA	1	0	0	0	1	0	0	0	0	0	0	2
BRACHIOPODA	0	0	0	0	1	1	1	0	2	1	0	2
COPEPODA	1	1	1	1	1	1	1	1	1	1	1	1
CRINOIDEA	0	0	0	0	0	0	1	0	0	0	0	1
APLACOPHORA	1	1	1	1	1	1	1	1	0	1	0	1

Cruise III (cont'd).

	STATION											
TAXON	C 1	C 6	C 2	C 3	C 7	C 8	C 9	C 4	C11	C 5	C12	Total
ARACHNIDA:ACARINA	0	0	1	0	1	1	0	0	1	0	0	1
ARCHIANNELIDA	0	0	0	0	0	0	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	0	0	0	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	1	0	0	0	0	0	0	0	1
ECHIURA	0	0	0	0	0	0	0	0	0	0	0	0
HEMICHORDATA	0	0	0	0	0	0	0	1	0	0	0	1
MYSIDACEA	0	0	0	0	0	0	0	1	0	0	0	1
MYSTACOCARIDA	0	0	1	0	0	0	0	0	0	0	0	1
NEMATODA	1	1	1	1	1	1	1	1	1	1	1	1
OSTEICHTHYES	1	0	0	0	0	0	0	0	0	0	0	1
POGONOPHORA/VESTIMENT	0	0	0	0	1	0	0	0	0	0	0	1
PRIAPULIDA	0	0	0	0	0	0	0	0	0	1	1	1
SCYPHOZOA	1	0	1	0	1	1	1	1	1	1	0	1
TURBELLARIA	0	0	0	1	0	0	1	0	0	1	0	1
Total	45	39	74	76	133	120	116	109	54	60	39	

Cruise IV.

	STATION															
TAXON	E1B	E1C	E1A	E1	E2B	E2	E2C	E2A	E2D	E2E	E3A	E3B	E3C	E3D	E3	E5	Total
TANAIDACEA	20	20	10	14	40	42	31	39	38	39	39	33	47	40	30	15	124
ISOPODA	6	5	6	7	23	25	24	18	21	19	16	22	26	20	15	14	87
BRYOZOA	6	6	6	10	4	8	5	5	7	5	10	9	8	11	7	6	29
CUMACEA	11	11	4	2	13	11	4	9	8	8	7	9	14	9	7	4	53
AMPHIPODA	9	8	7	2	14	10	8	11	10	11	13	12	17	14	11	3	45
BIVALVIA	19	17	15	18	10	9	7	8	10	9	14	12	12	14	9	8	32
GASTROPODA	3	4	2	4	3	2	1	3	3	5	7	2	5	6	2	1	21
PORIFERA	3	2	1	3	3	3	3	1	4	4	5	3	6	5	4	10	14
SIPUNCULA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
OSTRACODA	5	6	5	4	7	6	5	7	9	7	7	7	8	8	8	1	17
NEMERTEA	7	5	7	7	7	8	6	6	6	4	5	7	7	6	4	2	17
ASCIDIACEA	0	0	0	0	2	0	2	3	1	3	1	1	5	3	1	2	10
OPHIUROIDEA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
HYDROZOA	1	1	2	1	1	1	1	0	2	1	0	1	1	1	2	2	7
DECAPODA	1	1	2	1	0	1	2	1	0	3	0	0	0	0	0	0	7
HOLOTHUROIDEA	1	2	1	1	4	2	3	2	3	3	3	3	3	4	3	3	7
SCAPHOPODA	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
OLIGOCHAETA	1	1	0	0	1	2	2	1	2	0	3	4	1	4	1	2	5
ECHINOIDEA	0	1	0	1	1	1	1	0	0	1	1	1	0	1	1	1	3
SCLERACTINEA	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	2
ACTINIARIA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
KINORHYNCHA	2	1	1	1	0	0	0	0	0	0	0	0	1	0	1	0	2
PYCNOGONIDA	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	3
MISC. ANTHOZOA	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
ALCYONARIA	0	0	0	0	0	0	1	1	1	0	1	0	0	1	1	0	2
ASTEROIDEA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BRACHIOPODA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1
COPEPODA	2	2	1	1	1	2	2	2	1	1	2	2	2	1	2	2	2
CRINOIDEA	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1
APLACOPHORA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Cruise IV (cont'd).

	STATION																
TAXON	E1B	E1C	E1A	E1	E2B	E2	E2C	E2A	E2D	E2E	E3A	E3B	E3C	E3D	E3	E5	Total
ARACHNIDA:ACARINA	0	1	0	0	1	1	0	0	0	1	1	1	1	1	1	1	1
ARCHIANNELIDA	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
CEPHALOCHORDATA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECHIURA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HEMICHORDATA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
MYSIDACEA	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
MYSTACOCARIDA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NEMATODA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
OSTEICHTHYES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POGONOPH./VEST.	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1
PRIAPULIDA	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1
SCYPHOZOA	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
TURBELLARIA	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total	105	100	78	85	141	142	116	123	132	133	144	136	173	155	119	82	

Cruise V.

	STATION												
TAXON	WC1	WC5	WC7	WC8	WC4	WC2	WC6	WC10	WC9	WC3	W11	W12	Total
TANAIDACEA	8	25	12	19	24	11	29	22	34	28	20	25	86
ISOPODA	9	8	14	21	22	17	27	14	21	13	21	20	76
BRYOZOA	6	6	3	5	4	10	9	3	6	7	2	9	28
CUMACEA	3	12	4	4	4	1	12	2	6	4	2	0	35
AMPHIPODA	6	12	7	9	11	6	10	9	9	6	10	8	34
BIVALVIA	11	12	7	10	12	10	10	11	14	11	13	16	27
GASTROPODA	2	5	3	5	2	5	5	2	3	1	4	4	22
PORIFERA	5	6	1	0	4	4	5	1	2	2	4	3	15
SIPUNCULA	1	1	1	1	1	1	1	1	1	1	1	1	1
OSTRACODA	1	2	6	6	6	6	8	3	4	5	3	4	13
NEMERTEA	5	10	5	4	5	2	3	4	5	3	3	5	11
ASCIDIACEA	0	0	0	0	0	1	2	1	3	4	2	0	7
OPHIUROIDEA	1	1	1	1	1	1	1	1	1	1	1	1	1
HYDROZOA	1	3	3	0	1	2	1	0	0	1	0	0	6
DECAPODA	0	1	2	1	1	0	0	0	0	0	0	0	4
HOLOTHUROIDEA	0	1	0	0	1	0	0	0	1	2	4	3	5
SCAPHOPODA	1	1	1	1	1	1	1	1	1	1	1	1	1
OLIGOCHAETA	1	1	2	1	1	0	1	0	0	0	1	1	3
ECHINOIDEA	0	1	0	0	1	2	0	1	0	1	1	1	3
SCLERACTINEA	0	3	0	0	0	1	1	0	1	0	0	0	4
ACTINIARIA	0	0	0	0	0	0	0	0	0	0	0	0	0
KINORHYNCHA	0	0	0	0	0	0	0	0	0	0	0	0	0
PYCNOGONIDA	0	1	0	0	0	0	0	0	0	0	0	0	1
MISC. ANTHOZOA	0	0	0	0	0	0	0	0	0	0	0	1	1
ALCYONARIA	0	0	0	0	0	0	0	0	0	0	0	0	0
ASTEROIDEA	0	0	0	0	0	0	0	0	0	0	0	0	0
BRACHIOPODA	0	0	1	0	0	1	0	0	0	0	0	0	1
COPEPODA	1	1	2	1	1	1	2	1	2	1	1	1	2
CRINOIDEA	0	0	0	0	0	0	0	0	0	0	0	0	0
APLACOPHORA	1	1	1	1	1	1	1	1	1	1	1	1	1

Cruise V (cont'd)

TAXON	WC1	WC5	WC7	WC8	WC4	WC2	WC6	WC10	WC9	WC3	W11	W12	Total
	STATION												
ARACHNIDA:ACARINA	0	1	1	1	1	0	1	1	0	0	0	0	1
ARCHIANNELIDA	0	0	0	0	0	0	0	0	0	0	0	0	0
CEPHALOCHORDATA	0	0	0	0	0	0	0	0	0	0	0	0	0
CIRRIPEDIA	0	0	0	0	0	0	0	0	0	0	0	0	0
ECHIURA	0	0	0	0	0	0	0	0	0	0	0	0	0
HEMICHORDATA	0	1	0	0	0	0	0	0	0	0	0	0	1
MYSIDACEA	0	0	0	0	0	0	0	0	0	0	0	0	0
MYSTACOCARIDA	0	0	0	0	0	0	0	0	0	0	0	0	0
NEMATODA	1	1	1	1	1	1	1	1	1	1	1	1	1
OSTEICHTHYES	0	0	0	0	0	0	0	0	0	0	0	0	0
POGONOPHORA/VESTIMENT	0	0	0	0	0	0	0	1	0	0	1	0	1
PRIAPULIDA	0	0	0	0	0	0	1	0	0	0	0	0	1
SCYPHOZOA	1	1	1	1	1	1	0	1	1	1	1	1	1
TURBELLARIA	0	0	0	0	0	0	1	0	0	0	0	0	1
Total	65	118	79	93	107	86	133	82	117	95	98	107	

ATTACHMENT A2.3: Summary of Macrofaunal Diversity Data by Station and Cruise

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Cruise I: Central Transect

TAXON	C 1	C 2	C 3	C 4	C 5
	STATION				
TANAIDACEA	2.25	2.59	2.73	2.87	1.70
ISOPODA	1.04	2.17	2.91	3.12	1.87
BRYOZOA	0.00	0.69	1.33	1.69	0.00
CUMACEA	2.19	1.56	1.61	1.93	0.00
AMPHIPODA	2.23	1.62	2.26	1.74	0.00
BIVALVIA	2.11	1.75	1.97	2.30	1.48

Cruise II:

	Western Transect					Central Transect					Eastern Transect				
						STATION									
Taxon	W 1	W 2	W 3	W 4	W 5	C 1	C 2	C 3	C 4	C 5	E 1	E 2	E 3	E 4	E 5
TANAIDACEA	2.02	2.39	2.81	2.32	1.71	1.69	2.80	2.88	3.09	2.24	2.04	2.67	2.96	2.97	2.22
ISOPODA	0.88	2.28	1.78	2.71	1.10	0.55	2.90	2.67	2.94	1.32	1.75	1.97	1.97	2.91	2.31
BRYOZOA	1.24	0.00	0.69	0.69	1.83	1.92	1.62	1.79	1.62	0.69	1.17	0.00	1.10	1.15	1.10
CUMACEA	0.69	1.10	1.56	0.00	0.00	0.69	1.99	1.39	1.85	0.97	0.69	0.00	1.97	1.75	0.85
AMPHIPODA	0.69	0.56	0.69	0.00	0.00	1.60	2.00	1.99	1.92	0.00	0.00	1.58	1.55	1.10	0.00
BIVALVIA	1.40	1.79	2.02	2.54	1.21	1.61	2.20	2.11	2.16	2.05	2.13	1.96	2.00	2.28	0.93

Cruise III: Central Transect

	STATION										
TAXON	C 1	C 6	C 2	C 3	C 7	C 8	C 9	C 4	C11	C 5	C12
TANAIDACEA	1.51	1.61	2.51	2.27	2.71	2.63	2.83	3.01	1.70	2.39	1.71
ISOPODA	0.43	0.74	1.99	2.27	3.18	2.89	2.91	2.30	1.69	2.00	1.60
BRYOZOA	0.00	0.00	0.58	0.53	0.00	1.09	1.07	1.52	1.06	0.64	0.00
CUMACEA	0.53	0.00	1.35	1.07	1.85	1.92	1.99	0.69	0.00	0.00	0.97
AMPHIPODA	0.99	1.02	1.54	1.04	0.77	1.66	1.73	0.91	0.69	0.00	0.00
BIVALVIA	1.76	1.44	1.92	1.83	2.04	2.59	2.37	1.84	1.99	1.42	1.25

Cruise IV: Eastern Transect

	STATION															
TAXON	E1B	E1C	E1A	E1	E2B	E2	E2C	E2A	E2D	E2E	E3A	E3B	E3C	E3D	E3	E5
TANAIDACEA	2.69	2.63	2.05	2.35	3.32	3.23	2.95	3.06	3.24	3.25	3.20	3.15	3.39	3.23	3.08	2.60
ISOPODA	1.71	1.54	1.68	1.39	2.60	2.83	2.82	2.55	2.85	2.47	2.62	2.86	2.82	2.84	2.51	2.51
BRYOZOA	0.56	1.16	1.29	1.23	0.14	0.40	0.55	1.18	0.60	0.34	0.95	0.67	1.19	1.96	1.30	1.48
CUMACEA	2.27	2.17	1.06	0.66	2.41	2.06	1.35	1.76	2.02	1.78	1.73	1.93	2.33	2.06	1.85	1.17
AMPHIPODA	1.35	1.61	1.27	0.53	2.25	1.64	0.97	1.60	1.46	1.69	1.90	1.61	1.99	2.07	1.62	0.58
BIVALVIA	2.25	2.28	2.16	2.18	1.63	1.80	1.53	1.41	1.75	1.76	2.11	1.95	2.19	2.18	1.65	1.30

Cruise V: Western Central Transect

	STATION											
TAXON	WC1	WC5	WC7	WC8	WC4	WC2	WC6	WC10	WC9	WC3	WC11	WC12
TANAIDACEA	1.64	2.80	2.06	2.38	2.60	1.11	2.93	2.83	3.00	2.80	2.56	3.09
ISOPODA	1.82	1.99	2.16	2.59	2.64	2.52	3.07	2.50	2.82	2.33	2.51	2.66
BRYOZOA	1.53	0.74	0.40	1.08	1.06	1.55	1.35	0.90	1.23	1.23	0.00	1.67
CUMACEA	1.10	2.25	1.39	1.35	0.97	0.00	2.13	0.66	1.79	1.39	0.69	0.00
AMPHIPODA	1.02	1.50	1.32	1.07	0.96	1.02	1.29	0.38	1.58	0.66	1.78	1.58
BIVALVIA	2.00	2.04	1.59	1.53	1.98	1.58	1.71	2.03	2.02	1.85	2.19	2.55

ATTACHMENT A2.4: Polychaete Feeding Types

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Attachment A2.4

POLYCHAETE FEEDING TYPES

FAMILY	NODC	FEEDING TYPE	FC
ACROCIRRIDAE	51	SELECTIVE DEPOSIT FEEDER	SDF
AMPHARETIDAE	67	" " "	SDF
AMPHINOMIDAE	10	CARNIVORE	C
APHRODITIDAE	01	"	C
ARABELLIDAE	33	"	C
ARENICOLIDAE	62	NON-SELECT DEPOSIT FEED.	NSDF
BOGUEIDAE	76	" " "	NSDF
CAPITELLIDAE	60	" " "	NSDF
CHAETOPTERIDAE	49	SELECTIVE DEPOSIT FEEDER	SDF
CHRYSOPETALIDAE	08	CARNIVORE	C
CIRRATULIDAE	50	SELECTIVE DEPOSIT FEEDER	SDF
COSSURIDAE	52	NON-SELECT DEPOSIT FEED.	NSDF
CTENODRILIDAE	53	" " "	NSDF
DORVILLEIDAE	36	CARNIVORE	C
EULEPETHIDAE	05	"	C
EUNICIDAE	30	OMNIVORE	O
EUPHROSINIDAE	11	SELECTIVE DEPOSIT FEEDER	SDF
"FAMILY C"	99	CARNIVORE	C
FAUVELIOPSIDAE	55	NON-SELECT DEPOSIT FEED.	NSDF
FLABELLIGERIDAE	54	" " "	NSDF
GLYCERIDAE	27	CARNIVORE	C
GONIADIDAE	28	"	C
HARTMANIELLIDAE	77	"	C
HESIONIDAE	21	"	C
HETEROSPIONIDAE	47	SELECTIVE DEPOSIT FEEDER	SDF
IOSPILIDAE	17	CARNIVORE	C
LACYDONIIDAE	16	OMNIVORE	O
LUMBRINERIDAE	31	CARNIVORE	C
MAGELONIDAE	44	NON-SELECT DEPOSIT FEED.	NSDF
MALDANIDAE	63	" " "	NSDF
NEPHTYIDAE	25	OMNIVORE	O
NEREIDAE	24	"	O
ONUPHIDAE	29	SCAVENGER	S
OPHELIIDAE	58	NON-SELECT DEPOSIT FEED.	NSDF
ORBINIIDAE	40	" " "	NSDF
OWENIIDAE	64	SUSPENSION FEEDER	SF
PALMYRIDAE	09	CARNIVORE	C
PARAONIDAE	41	NON-SELECT DEPOSIT FEED.	NSDF
PHYLLODOCIDAE	13	CARNIVORE	C
PILARGIDAE	22	OMNIVORE	O
POECILOCHAETIDAE	46	SELECTIVE DEPOSIT FEEDER	SDF
POLYNOIDAE	02	CARNIVORE	C
QUESTIDAE	74	NON-SELECT DEPOSIT FEED.	NSDF
SABELLARIIDAE	65	SUSPENSION FEEDER	SF
SABELLIDAE	70	" "	SF
SCALIBREGMIDAE	57	SELECTIVE DEPOSIT FEEDER	SDF
SERPULIDAE	73	SUSPENSION FEEDER	SF

Attachment A2.4 (cont'd)

POLYCHAETE FEEDING TYPES

FAMILY	NODC	FEEDING TYPE	FC
SIGALIONIDAE	06	CARNIVORE	C
SPHAERODORIDAE	26	NON-SELECT DEPOSIT FEED.	NSDF
SPIONIDAE	43	SELECTIVE DEPOSIT FEEDER	SDF
STERNASPIDAE	59	NON-SELECT DEPOSIT FEED.	NSDF
SYLLIDAE	23	OMNIVORE	O
TEREBELLIDAE	68	SELECTIVE DEPOSIT FEEDER	SDF
TRICHOBRANCHIDAE	69	" " "	SDF
TROCHOCHAETIDAE	45	" " "	SDF
TYPHLOSCOLECIDAE	19	UNKNOWN	?

ATTACHMENT A2.5: Depth Ranges of 150 Most Abundant Polychaeter

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Attachment A2.5. Depth ranges of 150 most abundant polychaetes. (A = NODC code, B = minimum depth observed, C = maximum depth observed, D = taxa name.) The taxa are ordered by depth of maximum occurrence. (Depths are in meters.)

	A	B	C	D
1	5001250115	320	349	NEPHTYS INCISA
2	5001430503	505	505	PRIONOSPIO HETEROBRANCHIA?
3	5001430598	302	615	PRIONOSPIO SP.D
4	5001290399	320	615	NOTHRIA SP.A
5	5001310198	351	625	LUMBRINERIS "SP. J"
6	5001230791	444	625	EXOGONE "SP.H"
7	5001430599	320	629	PRIONOSPIO SP.A
8	5001430506	343	629	PRIONOSPIO STEENSTRUPI
9	5001600307	302	631	NOTOMASTUS HEMIPODUS
10	5001360203	298	633	PROTODORVILLEA KEFERSTEINI
11	5001870501	343	639	MELINNA CRISTATA
12	5001220199	344	639	ANCISTROSYLLIS "SP.A"
13	5001250303	335	834	AGLAOPHAMUS VERRILLI
14	5001260298	358	834	SPHAERODOROPSIS "SP.E"
15	5001400898	298	845	LEITOSCOLOPLOS FRAGILIS
16	5001230790	336	845	EXOGONE "SP.D"
17	5001411198	595	845	SABIDIUS SP.A
18	5001400998	358	847	CALIFIA SP.B
19	5001410222	302	850	ARICIDEA TAYLORI
20	5001700187	298	852	CHONE SP. N
21	5001230295	618	852	PIONOSYLLIS "SP. D"
22	5001700193	291	860	CHONE SP.B
23	5001700199	302	860	CHONE SP.A
24	5001230299	344	860	PIONOSYLLIS "SP.B"
25	5001290599	580	860	HYALINOECIA JUVENALIS
26	5001220999	291	870	LITOCORSA ANTENNATA
27	5001310116	351	885	LUMBRINERIS BREVIPES
28	5001060199	343	1007	PHOLOE "SP.C"
29	5001410298	459	1007	ARICIDEA ABRANCHIATA
30	5001230298	298	1032	PIONOSYLLIS "SP. H"
31	5001060101	320	1032	PHOLOE MINUTA?
32	5001630199	345	1032	ASYCHIS ATLANTICUS
33	5001440197	344	1147	MAGELONA SP. B
34	5001580698	580	1147	OPHELINA SP.D
35	5001701398	302	1198	FABRICIA SP.B
36	5001230306	336	1198	SYLLIS (EHLERSIA) CORNUTA
37	5001310104	291	1222	LUMBRINERIS LATREILLI
38	5001410224	335	1222	ARICIDEA (ACMIRA) SIMPLEX
39	5001580999	349	1222	AMMOTRYPANELLA SP. A
40	5001410299	351	1222	ARICIDEA SP. A
41	5001460199	298	1229	POECILOCHAETUS SP.A
42	5001291098	554	1229	PARONUPHIS SP.A-1
43	5001230297	298	1232	PIONOSYLLIS SP.A
44	5001670303	347	1232	AMPHICTEIS GUNNERI
45	5001260599	595	1232	SPHAEREPHESIA SP.A
46	5001231999	618	1235	BRANIELLA "SP.A"
47	5001299998	298	1236	SARSONUPHIS SP. A
48	5001180101	302	1236	PARALACYDONIA PARADOXA

Attachment A2.5 (cont'd)

	A	B	C	D
49	5001410102	340	1236	AUDICURA BELGICAE
50	5001690197	347	1238	TEREBELLIDES DISTINCTA
51	5001700210	291	1330	EUCHONE ROSEA
52	5001409999	344	1330	MICRORBINIA LINEA
53	5001230399	347	1330	SYLLIS (EHLERSIA) SP A
54	5001410605	353	1330	CIRROPHORUS BRANCHIATUS
55	5001400399	554	1330	SCOLOPLOS SP A
56	5001580698	615	1330	OPHELINA SP B
57	5001409899	291	1389	LEITOSCOLOPLOS SP A
58	5001600299	358	1390	HETEROMASTUS SP A
59	5001230598	639	1390	SPHAEROSYLLIS SP B
60	5001280601	547	1419	PROGONIADA REGULARIS
61	5001700204	298	1433	EUCHONE INCOLOR?
62	5001600310	291	1440	NOTOMASTUS AMERICANUS
63	5001310301	298	1440	LUMBRINERIDES ACUTA?
64	5001410211	344	1440	ARICIDEA CERRUTI
65	5001230898	353	1440	SPHAEROSYLLIS PIRIFEROPSIS
66	5001580695	353	1440	OPHELINA SP E
67	5001410215	798	1444	ARICIDEA LOPEZI LOPEZI
68	5001430591	340	1482	PRIONOSPIO SP B
69	5001580103	340	1482	OPHELINA CYLINDRICAUDATA
70	5001640299	351	1482	MYRIOCHELE "SP. E"
71	5001230897	366	1482	SPHAEROSYLLIS RENAUDAE?
72	5001430594	320	1506	PRIONOSPIO EHLERSI
73	5001230796	335	1506	EXOGONE SP D
74	5001700198	622	1506	CHONE SP D
75	5001299997	298	1507	SARSONUPHIS HARTMANAE
76	5001310124	302	1507	LUMBRINERIS VERRILLI
77	5001630397	302	1507	MALDANE "SP A"
78	5001580699	320	1507	OPHELINA SP A
79	5001607899	320	1507	NEOMEDIOMASTUS SP A
80	5001640201	320	1507	MYRIOCHELE HEERI?
81	5001671901	320	1507	AUCHENOPLAX CRINITA
82	5001690198	336	1507	TEREBELLIDES ATLANTIS
83	5001630302	366	1507	MALDANE GLEBIFEX
84	5001230701	618	1507	EXOGONE DISPAR
85	5001670299	291	2118	AMPHARETE "SP A"
86	5001290397	347	2124	NOTHRIA TEXTOR
87	5001100401	291	2377	PARAMPHINOME JEFFREYSII
88	5001540404	302	2377	DIPLOCIRRUS CAPENSIS
89	5001590101	335	2377	STERNASPIS SCUTATA
90	5001410228	351	2377	ARICIDEA TRILOBATA?
91	5001289999	350	2377	BATHYGLYCINDE "SP A"
92	5001230795	615	2377	EXOGONE LONGICIRRUS?
93	5001490302	291	2470	SPIOCHAETOPTERUS COSTARUM
94	5001520103	320	2470	COSSURA DELTA
95	5001431005	335	2470	SPIOPHANES WIGLEYI
96	5001580997	353	2470	TACHYTRYPANE SP C

Attachment A2.5 (cont'd)

	A	B	C	D
97	5001580694	455	2470	OPHELINA SP.7
98	5001230710	505	2470	EXOGONE ATLANTICA
99	5001230798	291	2524	EXOGONE SP.B
100	5001430502	291	2524	PRIONOSPIO CIRRIFERA
101	5001130599	347	2524	MYSTIDES SP. A
102	5001250304	349	2524	AGLAOPHAMUS CIRCINATA
103	5001060399	605	2524	STHENELAIS SP.A
104	5001230795	618	2524	EXOGONE "SP. C"
105	5001690101	291	2533	TEREBELLIDES STROEMI
106	5001431006	345	2533	SPIOPHANES MISSIONENSIS
107	5001580999	291	2540	TACHYTRYPANE SP.A
108	5001100499	298	2540	PARAMPHINOME SP. A
109	5001600699	335	2540	BARANTOLLA "SP. A"
110	5001220501	345	2540	SYNELMIS KLATTI
111	5001411101	344	2540	SABIDIUS CORNATUS
112	5001400306	291	2540	SCOLOPLOS "SP.H"
113	5001520198	353	2540	COSSURA HETEROCHAETA
114	5001230792	358	2540	EXOGONE "SP.I"
115	5001550199	366	2540	FAUVELIOPSIS "SP.A"
116	5001439699	298	2853	AUROSPIO DIBRANCHIATA
117	5001500495	347	2853	CHAETOZONE "SP.H"
118	5001430201	351	2853	LAONICE CIRRATA
119	5001672299	366	2853	ECLYSIPPE "SP. B"
120	5001240601	618	2853	CERATOCEPHALE LOVENI
121	5001589999	335	2897	KESUN SP. A
122	5001540499	291	2900	DIPLOCIRRUS "SP.A"
123	5001431004	291	2902	SPIOPHANES BERKELEYORUM
124	5001700195	291	2904	CHONE SP.L
125	5001431001	298	2904	SPIOPHANES BOMBYX
126	5001500306	298	2904	THARYX ANNULOSUS?
127	5001700299	298	2904	EUCHONE "SP.A"
128	5001319999	302	2904	AUGENERIA BIDENS
129	5001240603	335	2904	CERATOCEPHALE OCULATA
130	5001580901	444	2904	TACHYTRYPANE JEFFREYSII
131	5001410208	291	2945	ARICIDEA CATHERINAE
132	5001600402	291	2945	MEDIOMASTUS CALIFORNIENSIS
133	5001310302	298	2945	LUMBRINERIDES DAYI
134	5001410214	302	2945	ARICIDEA (ARICIDEA) FRAGILIS
135	5001410603	340	2945	CIRROPHORUS LYRA
136	5001602099	347	2945	PERESIELLA SPATHULATA?
137	5001220201	320	2953	SIGAMBRA TENTACULATA
138	5001410803	335	2953	LEVINSENIA UNCINATA
139	5001410201	291	2959	ARICIDEA SUECICA
140	5001410801	291	2959	LEVINSENIA GRACILIS
141	5001500307	291	2959	THARYX MARIONI
142	5001550198	291	2959	FAUVELIOPSIS SP.B
143	5001600306	291	2959	NOTOMASTUS LATERICEUS
144	5001640399	343	2959	MYRIOWENIA SP.A

Attachment A2.5 (cont'd)

	A	B	C	D
145	5001270107	344	2959	GLYCERA PAPILLOSA?
146	5001500499	344	2959	CHAETOZONE "SP.C"
147	5001570201	344	2959	ASCLEROCHEILUS BERINGIANUS
148	5001230799	347	2959	EXOGONE "SP.A"
149	5001470101	347	2959	HETEROSPIO LONGISSIMA?
150	5001130501	622	2959	MYSTIDES BOREALIS

ATTACHMENT A2.6: Polychaete References

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Attachment A2.6. Polychaete References.

1 Banse, K. and K.D. Hobson. 1974. Benthic errantiate polychaetes of British Columbia and Washington. Bull. Fish. Res. Bd. Canada, Bull. 185.

2. Blake, J.A. 1985. POLYCHAETA FROM THE VICINITY OF DEEP-SEA GEOTHERMAL VENTS IN THE EASTERN PACIFIC I: EUPHROSINIDAE, PHYLLODOCIDAE, HESIONIDAE, NEREIDIDAE, GLYCERIDAE, DORVILLEIDAE, ORBINIIDAE, AND MALDANIDAE. BIOL. SOC. WASH. BULL. No. 6, 1985, pp.67-101.

3. Day, J.H. 1967. A Monograph on the Polychaetes of South Africa, Part I. Errantia, Part II. Sedentaria. British Museum (Natural History) London. Pub. No.656.

4. _______ 1973. New Polychaeta from Beaufort, with a Key to All Species Recorded from North Carolina. NOAA Technical Report NMFS CIRC-375.

5. Fauchald, K. 1968. Onuphidae (Polychaeta) from Western Mexico. Allan Hancock Monographs in Marine Biology. No.3. University of Southern California, Los Angeles, California.

6. __________ 1977. The Polychaete Worms--Definitions and Keys to the Orders, Families, and Genera. Natural History Museum of Los Angeles County, Science Series 28:1-190.

7. __________ 1982a. TWO NEW SPECIES OF ONUPHIS (ONUPHIDAE:POLYCHAETA) FROM URUGUAY. PROC. BIOL. SOC. WASH. 95(1), 1982, pp.203-209.

8. ___________ 1982b. Revision of Onuphis, Nothria, and Paradiopatra (Polychaeta:Onuphidae) Based upon Type Material. Smithsonian Contributions to Zoology; No.356.

9. Fauvel, P. 1923. Faune de France. 5. Polychetes Errantes.
1927. Faune de France.14. Polychetes Sedentaires.

10. Gardiner, S.L. 1975. ERRANT POLYCHAETE ANNELIDS FROM NORTH CAROLINA. Journal of the Elisha Mitchell Scientific Society, Vol. 91, No. 3.

11. Hartman, O. 1939. Polychaetous Annelids, Part I. Aphroditidae to Pisionidae. Allan Hancock Pacific Expeditions Volume 7, Nos. 1-2. University of Southern California Press, Los Angeles, California.

Attachment A2.6 (cont'd)

12. Hartman, O. 1940. Polychaetous Annelida, Part II. Chrysopetalidae to Goniadidae. Allan Hancock Pacific Expeditions, Vol. 7, No. 3. Univ. South. Calif. Press, L. A., Ca.

13. ________ 1944a. Polychaetous Annelida, Part V. Eunicea. Allan Hancock Pacific Expeditions, Vol. 10, No. 1. Univ. South. Calif. Press, L.A., Ca.

14. ________ 1944b. Polychaetous Annelida from California Including the Descriptions of Two New Genera and Nine New Species. Polychaetous Annelida, Part VI. Paraonidae, Magelonidae, Longosomidae, Ctenodrilidae, and Sabellariidae. Allan Hancock Pacific Expeditions, Vol. 10, Nos. 2-3. Univ. South. Calif. Press, L.A.,Ca.

15. ________ 1947. Polychaetous Annelida, Part VII Capitellidae; Part VIII. Pilargiidae. Allan Hancock Pacific Expeditions, Vol. 10, Nos. 4-5. Univ. South. Calif. Press, L.A., Ca.

16. ________ 1965. Deep-water Benthic Polychaetous Annelida Off New England to Bermuda and Other North Atlantic Areas. Allan Hancock Foundation Publications Occasional Paper No. 28. Univ. South. Calif. Press, L.A., Ca.

17. ________ 1968. Atlas of the Errantiate Polychaetous Annelida from California. Allan Hancock Foundation. Univ. South. Calif., L.A., Ca.

18. ________ 1969. Atlas of the Sedentariate Polychaetous Annelida from California. Allan Hancock Foundation. Univ. South. Calif., L.A., Ca.

19. Hartman, O. and K. Fauchald. 1971. Deep-water Benthic Polychaetous Annelida Off New England to Bermuda and Other North Atlantic Areas, Part II. Allan Hancock Monographs in Marine Biology, No. 6. Univ. South, Calif., L.A., Ca.

20. Imajima, M. and O. Hartman. 1964. The Polychaetous Annelida of Japan, Part I., Part II. Allan Hancock Foundation Publications Occasional Paper No. 26. Univ. South. Calif., L.A., Ca.

21. Hobson, K.D. and K. Banse. 1981. Sedentariate and archiannelid polychaetes of British Columbia and Washington. Canadian Bulletin of Fisheries and Aquatic Sciences, Bull. 209.

22. Hutchings, P.A., Editor. 1984. Proceedings of the First International Polychaete Conference. Sydney, Australia, July 1983. Linnean Society of New South Wales.

23. Jones, M.L..1963. Four New Species of *Magelona* (Annelida, Polychaeta) and a Rediscription of *Magelona longicornis* Johnson. American Museum Novitates, No. 2164.

24. Light, W.J. 1978. "Spionidae (Polychaeta, Annelida)" Invertebrates of the San Francisco Bay Estuary System. Welton E. Lee, Editor. California Academy of Sciences. The Boxwood Press.

25. Maciolek, N.J. 1981. A NEW GENUS AND SPECIES OF SPIONIDAE (ANNELIDA:POLYCHAETA) FROM THE NORTH AND SOUTH ATLANTIC. PROC. BIOL. SOC. WASH. 94(1), 1981,pp. 228-239.

26. ________ 1985. A revision of the genus *Prionospio* Malmgren, with special emphasis on species from the Atlantic Ocean, and new records of species belonging to the genera *Apoprionospio* Foster and *Paraprionospio* Caullery (Polychaeta, Annelida, Spionidae). Zoological Journal of the Linnean Society (1985),84: 325-383.

27. Miura, T. 1980. Lumbrineridae (Annelides Polychetes) abyssaux recoltes au cours de campagnes du Centre Oceanologique de Bretagne dans l'Atlantique et la Mediterranee. Bull. Mus. natn. Hist. nat., Paris, 4e ser., 2, 1980, section A, no 4: 1019-1057.

28. Orensanz, J.M. 1976. Los Anelidos Poliquetos de la Provincia Biogeografica Argentina. IX. Poecilochaetidae y Cossuridae.Comunicaciones Zoologicas del Museo de Historia Natural de Montevideo, Vol. X, No. 140.

29. Perkins, T.H. 1979. LUMBRINERIDAE, ARABELLIDAE, AND DORVILLEIDAE (POLYCHAETA), PRINCIPALLY FROM FLORIDA, WITH DESCRIPTIONS OF SIX NEW SPECIES. PROC. BIOL. SOC. WASH. 92(3), 1979, pp. 415-465.

30. ________ 1980a. REVIEW OF SPECIES PREVIOUSLY REFERRED TO *CERATONEREIS MIRABILIS*, AND DESCRIPTIONS OF NEW SPECIES OF *CERATONEREIS*, *NEPHTYS*, AND *GONIADA* (POLYCHAETA). PROC. BIOL. SOC. WASH. 93(1), 1980, pp. 1-49.

31. Perkins, T.H. 1980b. SYLLIDAE (POLYCHAETA), PRINCIPALLY FROM FLORIDA, WITH DESCRIPTIONS OF A NEW GENUS AND TWENTY-ONE NEW SPECIES. PROC. BIOL.SOC. WASH. 93(4), 1980, pp. 1080-1172.

32. ________ 1984a. REVISION OF DEMONAX KINBERG, HYPSICOMUS GRUBE, AND NOTAULAX TAUBER, WITH A REVIEW OF MEGALOMMA JOHANSSON FROM FLORIDA (POLYCHAETA: SABELLIDAE). PROC. BIOL.SOC. WASH. 97(2), 1984, pp.285-368.

33. ________ 1984b. NEW SPECIES OF PHYLLODOCIDAE AND HESIONIDAE (POLYCHAETA), PRINCIPALLY FROM FLORIDA. PROC. BIOL.SOC. WASH. 97(3), 1984, pp. 555-582.

34. Perkins, T.H. and T. Savage. 1975. A Bibliography and Checklist of Polychaetous Annelids of Florida, the Gulf of Mexico, and the Caribbean Region. Florida Marine Research Publications, No. 14.

35. Pettibone, M.H. 1962. NEW SPECIES OF POLYCHAETE WORMS (SPIONIDAE;SPIOPHANES) FROM THE EAST AND WEST COAST OF NORTH AMERICA. PROC. BIOL. SOC. WASH. Vol. 75, pp. 77-88.

36. Reish, D.J. and K. Fauchald. 1977. Essays on Polychaetous Annelids in Memory of Dr. Olga Hartman. Special Publication of the Allan Hancock Foundation. Univ. South. Calif., L.A., Ca.

37. Strelzov, V.E. 1979. Polychaete Worms of the Family Paraonidae Cerruti, 1909 (Polychaeta, Sedentaria). U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia 22161.

38. Uebelacker, J.M. and P.G. Johnson, Editors. 1984. Taxonomic Guide to the Polychaetes of the Northern Gulf of Mexico. Final Report to the Minerals Management Service, contract 14-12-001-29091. Barry A. Vittor & Associates, Inc., Mobile, Alabama.

39. Ushakov, P.V. 1955. Polychaetes of the Far Eastern Seas of the U.S.S.R. Akademiya Nauk Soyuza Sovetskikh Sotsialisticheskikh Respublik. Keys to the Fauna of the U.S.S.R. published by the Zoological Institute of the Academy of Sciences of the U.S.S.R., No. 56.

40. Wainright, S.C. and T.H. Perkins. 1982. GYMNODORVILLEA FLORIDANA, A NEW GENUS AND SPECIES OF DORVILLEIDAE (POLYCHAETA) FROM SOUTHEASTERN FLORIDA. PROC. BIOL. SOC. WASH. 95(4), 1982, pp. 694-701.

41. Williams, S.J. 1984. The status of *Terebellides stroemi* (Polychaeta; Trichobranchidae) as a cosmopolitan species, based on a worldwide morphological survey, including description of new species. Proceedings of the First International Polychaete Conference, Sydney, edited by P.A. Hutchings, published by the Linnean Society of New South Wales, 1984, pp. 118-142.

42. Wolf, P.S. 1983. A REVISION OF THE BOGUEIDAE HARTMAN AND FAUCHALD, 1971, AND ITS REDUCTION TO BOGUEINAE, A SUBFAMILY OF MALDANIDAE (POLYCHAETA). PROC. BIOL. SOC. WASH. 96(2), 1983, pp. 238-249.

43. ________ 1986. THREE NEW SPECIES OF PILARGIDAE (ANNELIDA:POLYCHAETA) FROM THE EAST COAST OF FLORIDA, PUERTO RICO, AND THE GULF OF MEXICO. PROC. BIOL.SOC. WASH. 99(3), 1986, pp. 464-471.

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ATTACHMENT A2.7: Annotated List of Abundant Polychaete Species

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Attachment A2.7.

Litocorsa antennata (Pilargidae) Wolf, 1986.
Geographic Distribution: Gulf of Mexico (Florida to Texas), Puerto Rico.*,**
Depth Range: 12-145m*,*. Depth range extension to: 870m
Feeding Type: Omnivore**

Aurospio dibranchiata (Spionidae) Maciolek, 1981.
GD: North and South Atlantic.**
DR: 300-3600m**
FT: Selective Deposit Feeder*
Range extension: Gulf of Mexico

Tachytrypane sp. A (Opheliidae)
GD: Gulf of Mexico
DR: 291-2540m
FT: Non-selective Deposit Feeder*

Spiophanes berkeleyorum (Spionidae) Pettibone, 1962.
GD: North Pacific; Gulf of Mexico**,**
DR: Intertidal-465m**
FT: Selective Deposit Feeder*
Depth extension to: 2470m

Aricidea suecica (Paraonidae) Eliason, 1920.
GD: North Atlantic, North Pacific, Arctic, Gulf of Mexico**
DR: 5-2000m*
FT: Non-selective Deposit Feeder*
DE: 2959m

Pholoe "sp.C" (Sigalionidae) Wolf, 1984.
GD: Gulf of Mexico (Florida)**
DR: 177-189m**
FT: Carnivore**
RE: Central to western Gulf of Mexico (see fig.)
DE: 1007m

Maldane "sp. A" (Maldanidae) Wolf, 1984.
GD: Gulf of Mexico (Florida)**
DR: 180m**
FT: Non-selective Deposit Feeder*,**
RE: North-central Gulf of Mexico
DE: 1507m

Prionospio ehlersi (Spionidae) Fauvel, 1928.
GD: Widespread (Atlantic, Pacific, Mediterranean)**
DR: 524-1700m**
FT: Selective Deposit Feeder*
RE: Gulf of Mexico
DE: 320m

Attachment A2.7 (cont'd).

Levinsenia gracilis (Paraonidae)(Tauber,1879)
GD: Cosmopolitan sub-antarctic[3,4]
DR: 5.5-3860m[3,7]
FT: Non-selective Deposit Feeder[3]

Fauveliopsis sp. B (Fauveliopsidae)
GD: Gulf of Mexico
DR: 291-2959m
FT: Non-selective Deposit Feeder[3,4]

Sarsonuphis hartmanae (Onuphidae) (Kirkegaard, 1980)
GD: North Atlantic; Gulf of Mexico[4],[3,4]
DR: 37-4265m[4]
FT: Scavenger[3],[3,4]

Prionospio cirrifera (Spionidae) Wiren, 1883.
GD: Beaufort Sea; North Atlantic[3,4]
DR: 11-2900m[3,4]
FT: Selective Deposit Feeder[3]
RE: Gulf of Mexico?(previous reports confused)

Tharyx marioni (Cirratulidae) (Saint-Joseph, 1894)
GD: Widespread (Atlantic, Pacific)[1,4]
DR: 1-1000m[1,4]
FT: Selective Deposit Feeder[3]
RE: Gulf of Mexico
DE: 2959m

Lumbrinerides dayi (Lumbrineridae) Perkins, 197[illegible].
GD: North Carolina; Florida; Puerto Rico; Gulf of Mexico[3,4]
DR: 20-189m[3,4]
FT: Carnivore[3]
DE: 2945m

Ceratocephale oculata (Nereidae) Banse, 1977.
GD: North Carolina; Gulf of Mexico[3,4]
DR: 15-35m[3,4]
FT: Omnivore[3]
DE: 2904m

Paralacydonia paradoxa (Lacydoniidae) Fauvel, 1913.
GD: Widespread[3,4]
DR: 7-5498m[3,4]
FT: Omnivore[3,4]

Tharyx annulosum? (Cirratulidae) Hartman,1965.
GD: New England; northeastern South America; Gulf of Mexico[1,4],[3,4]
DR: 15-4540m[1,4]
FT: Selective Deposit Feeder[3]

Attachment A2.7 (cont'd).

Paramphinome jeffreysii (Amphinomidae) (McIntosh, 1868)
GD: North Atlantic; northeastern South America'*
DR: 36-5304m'*
FT: Carnivore*
RE: Gulf of Mexico (previously reported as *P. pulchella*)

Terebellides stroemi (Trichobranchidae) Sars, 1835.
GD: (Previously considered cosmopolitan; now thought to be restricted to the North Atlantic. Specimens in this study identified as *T. stroemi* probably should be assigned to *T. atlantis* or *T. distincta*)*:

Diplocirrus capensis (Flabelligeridae) Day, 1961.
GD: South Africa; North Carolina; Gulf of Mexico**
DR: 11-200m**
FT: Non-selective Deposit Feeder*
DE: 2377m

Terebellides atlantis (Trichobranchidae) Williams, 1984.
GD: New England Slope*:
DR: 400-508m*:
FT: Selective Deposit Feeder**
RE: Gulf of Mexico
DE: 1507m

Terebellides distincta (Trichobranchidae) Williams, 1984.
GD: New England Slope*:
DR: 466-508m*:
FT: Selective Deposit Feeder**
RE: Gulf of Mexico
DE: 357-1236m

Paramphinome "sp. A" (Amphinomidae) Gathof, 1984.
GD: Gulf of Mexico**
DR: 75m**
FT: Carnivore*
DE: 2540m

Spiophanes bombyx (Spionidae) (Claparede, 1870)
GD: Cosmopolitan**
DR: 0-118m**
FT: Selective Deposit Feeder*
DE: 2904m

Diplocirrus "sp. A" (Flabelligeridae) Milligan, 1984.
GD: Gulf of Mexico**
DR: 19-106m**
FT: Non-selective Deposit Feeder*
DE: 2900m

Attachment A2.7 (cont'd).

Cirrophorus lyra (Paraonidae)(Southern, 1914)
GD: North Atlantic, South Africa, Mediterranean[37]
DR: 2-1060m[37]
FT: Non-selective Deposit Feeder[3]
RE: Gulf of Mexico
DE: 2945m

Lumbrineris verrilli (Lumbrineridae) Perkins, 1979.
GD: East coast of Florida; Gulf of Mexico[38]
DR: 3-189m[38]
FT: Carnivore[3]
DE: 1507m

Euchone incolor? (Sabellidae) Hartman, 1965.
GD: Atlantic and Pacific North America; Gulf of Mexico[38]
DR: 17.5-2500m[38]
FT: Suspension Feeder[3]

Levinsenia uncinata (Paraonidae) (Hartman, 1965)
GD: Atlantic; Sea of New Guinea; central North Pacific[37]
DR: 1044-5881m[37]
FT: Non-selective Deposit Feeder[3]
RE: Gulf of Mexico
DE: 335m

Aricidea lopezi lopezi (Paraonidae) Berkeley and Berkeley, 1956.
GD: Widespread[37]
DR: 6-1100m[37]
FT: Non-selective Deposit Feeder[3]
DE: 1444m

Barantolla "sp. A" (Capitellidae) Ewing, 1984.
GD: Gulf of Mexico (southern Florida)[38]
DR: 87-91m[38]
FT: Non-selective Deposit Feeder[3]
RE: Northwestern and northcentral Gulf of Mexico
DE: 2540m

Glycera papillosa? (Glyceridae) Grube, 1857.
GD: South Africa; Peru; Chile; North Carolina; Gulf of Mexico[38]
DR: Intertidal - 200m[38]
FT: Carnivore[3]
DE: 2959m

Amphareta "sp. A" (Ampharetidae) Uebelacker, 1984.
GD: Gulf of Mexico[38]
DR: 10-189m[38]
FT: Selective Deposit Feeder[3]
DE: 2118m

Attachment A2.7 (cont'd).

Syllis (Ehlersi) cornuta (Syllidae) Rathke, 1843.
GD: Cosmopolitan[38]
DR: Intertidal - 2560m[38]
FT: Omnivore[3,38]

Aricidea fragilis (Paraonidae) Webster, 1879.
GD: Widespread (Atlantic, Pacific, Mediterranean, Gulf of Mexico)[37]
DR: 0-54m[37]
FT: Non-selective Deposit Feeder[3]
DE: 2945m

Sabidius cornatus (Paraonidae) (Hartman, 1965)
GD: Atlantic and Pacific[37]
DR: 400-3388m[37]
FT: Non-selective Deposit Feeder[3]
RE: Gulf of Mexico.
DE: 344m

Myriochele heeri? (Oweniidae) Malmgren, 1869.
GD: Cosmopolitan[18]
DR: Eurybathic[18]
FT: Suspension Feeder[3]

Aricidea simplex (Paraonidae) Day, 1963.
GD: Widespread (Atlantic, Pacific, Gulf of Mexico)[38]
DR: 35-1072m[38]
FT: Non-selective Deposit Feeder[3]
DE: 1222m

Sigambra tentaculata (Pilargidae) (Treadwell, 1941)
GD: Widespread[38]
DR: Intertidal - 5121m[38]
FT: Omnivore[3]

Notomastus americanus (Capitellidae) Day, 1973.
GD: North Carolina; Gulf of Mexico[38]
DR: 80-100m[38]
FT: Non-selective Deposit Feeder[3,38]
DE: 1440m

Aglaophamus circinata (Nephtyidae) (Verrill, 1874)
GD: Boreal and temperate western Atlantic; Gulf of Mexico[38]
DR: 10-189m[38]
FT: Omnivore[3,38]
DE: 2524m

Notomastus latericeus (Capitellidae) Sars, 1851.
GD: Cosmopolitan[38]
DR: Intertidal - 4360m[38]
FT: Non-selective Deposit Feeder[3,38]

Attachment A2.7 (cont'd).

Synelmis klatti (Pilargidae) (Friedrich, 1951)
GD: North Sea; Scotland; Gulf of Mexico[38]
DR: 11-680m[38]
FT: Omnivore[3]
DE: 2540m

Tachytrypane jeffreysii (Opheliidae) McIntosh, 1879.
GD: North Atlantic[18]
DR: Abyssal; 780-4850m[18]
FT: Non-selective Deposit Feeder[3]
RE: Gulf of Mexico
DE: 444m

Notomastus hemipodus (Capitellidae) Hartman, 1945.
GD: North Carolina; California; Gulf of Mexico[38]
DR: Intertidal - 120m[38]
FT: Non-selective Deposit Feeder[3,38]
DE: 631m

Heterospio longissima? (Heterospionidae) Ehlers, 1874.
GD: Widespread (North Atlantic; Mediterranean; Japan; Gulf of Mexico)[38]
DR: 35-4950m[38]
FT: Selective Deposit Feeder[3]

Aglaophamus verrilli (Nephtyidae) (McIntosh, 1885)
GD: Temperate and subtropical western Atlantic; Gulf of Mexico[38]
DR: Estuarine - 189m[38]
FT: Omnivore[3]
DE: 834m

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* Numbers refer to citations listed in "Polychaete References."

ATTACHMENT A2.8: Distribution of Abundant Polychaete Species (Taxa name is provided on each map, annotational notes for each taxa can be found in Attachment A2.7;)

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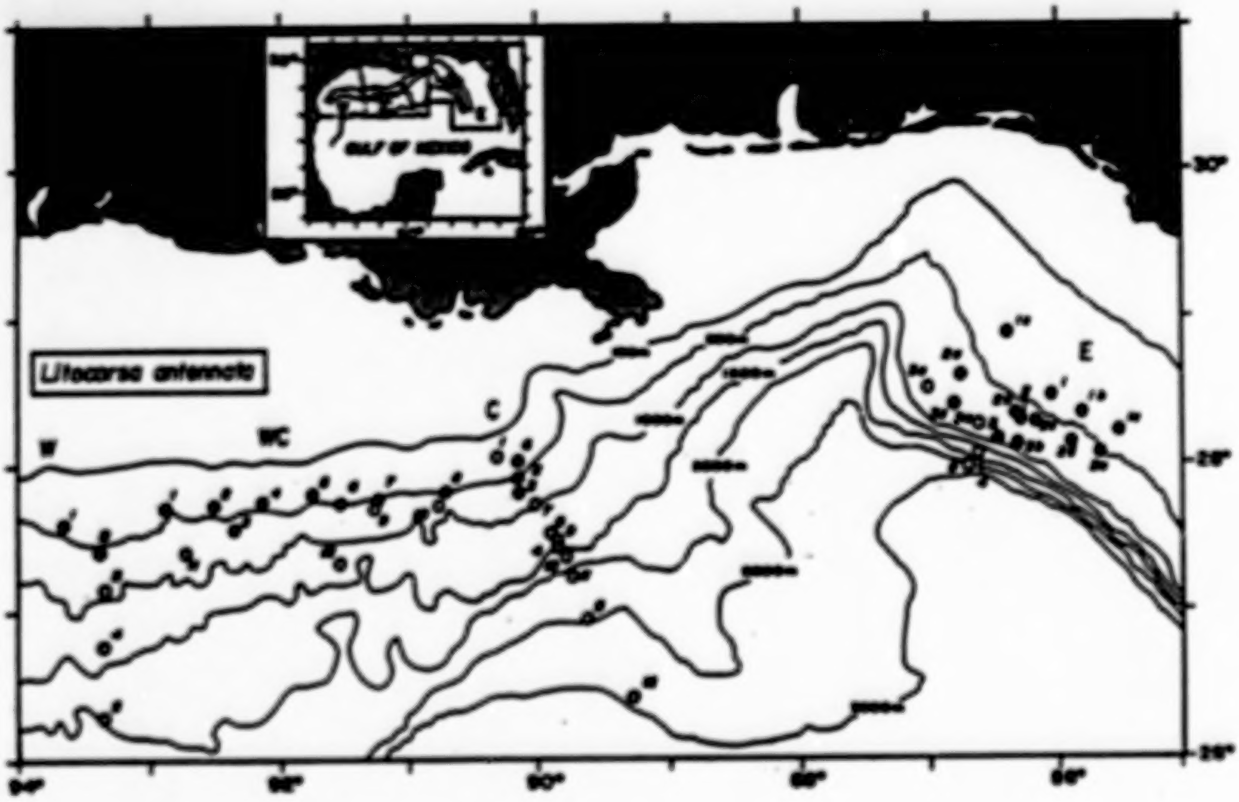
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GULF OF MEXICO
Aurospio dibranchiata
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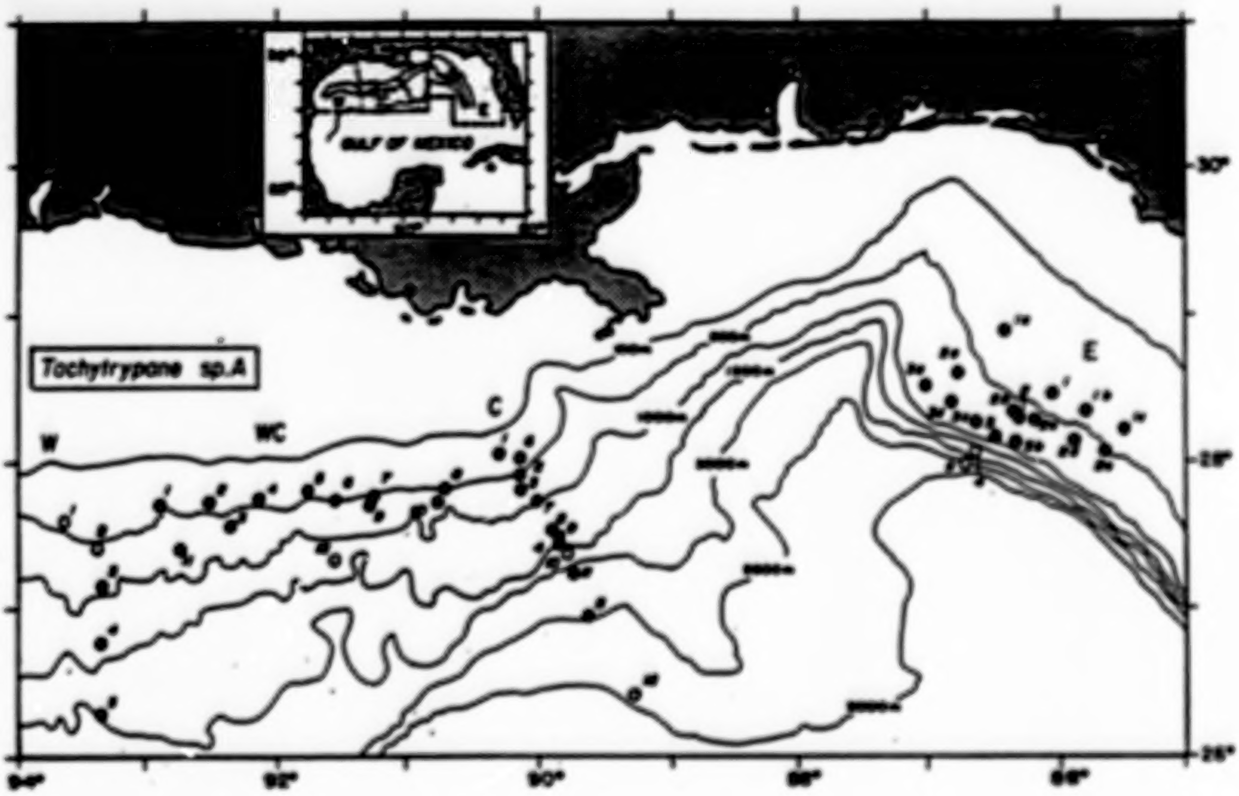
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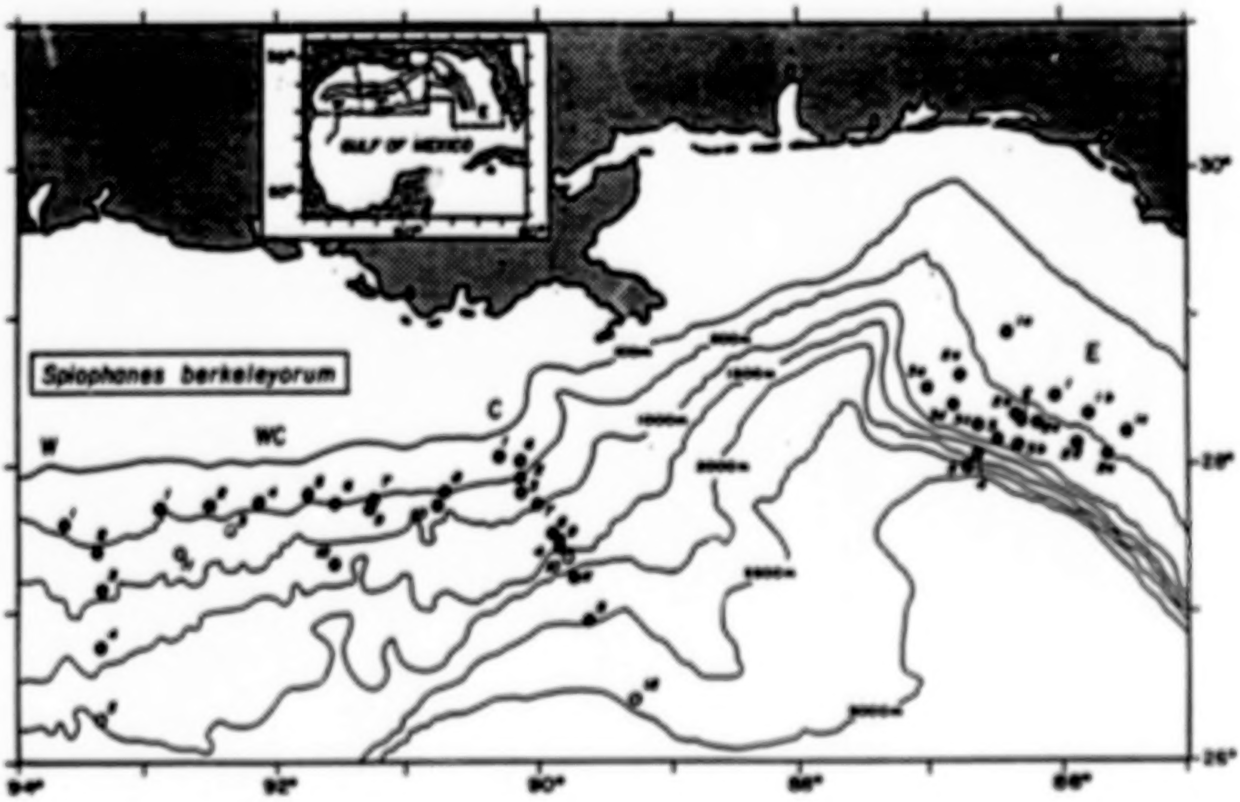
Spiophanes berkeleyorum
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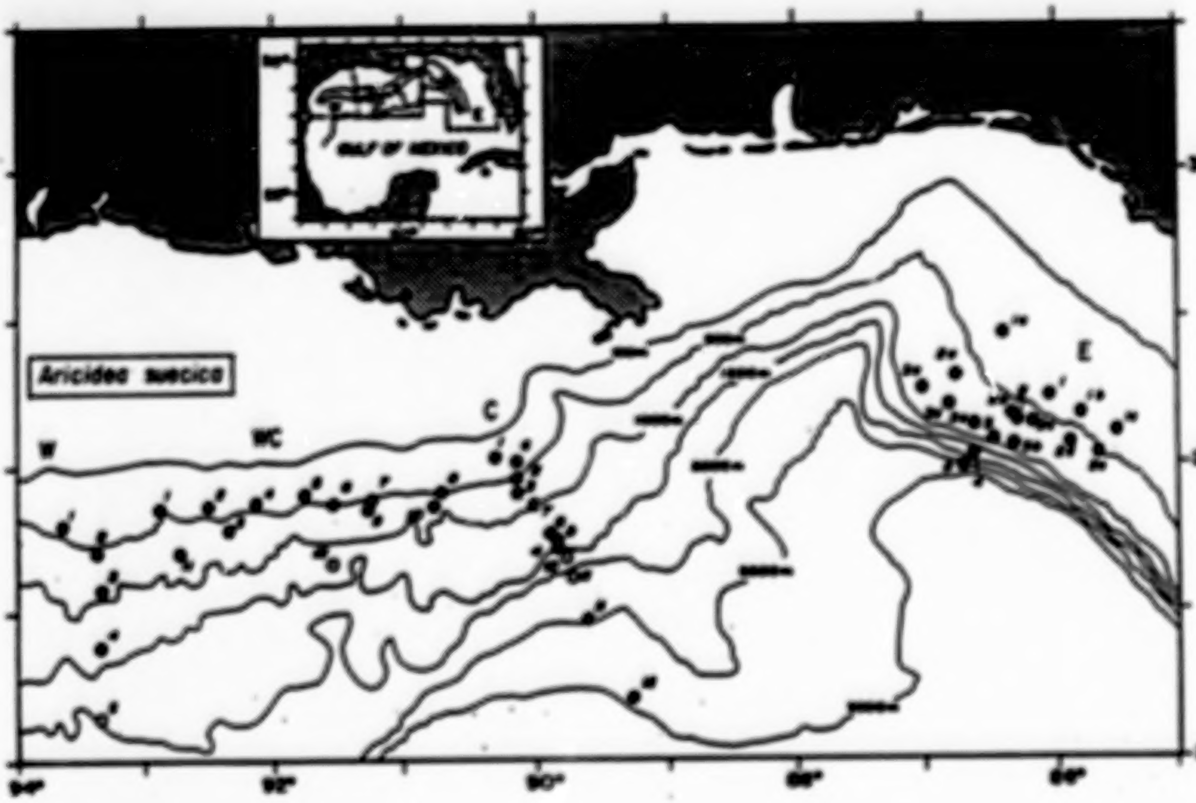
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Aricidea suecica
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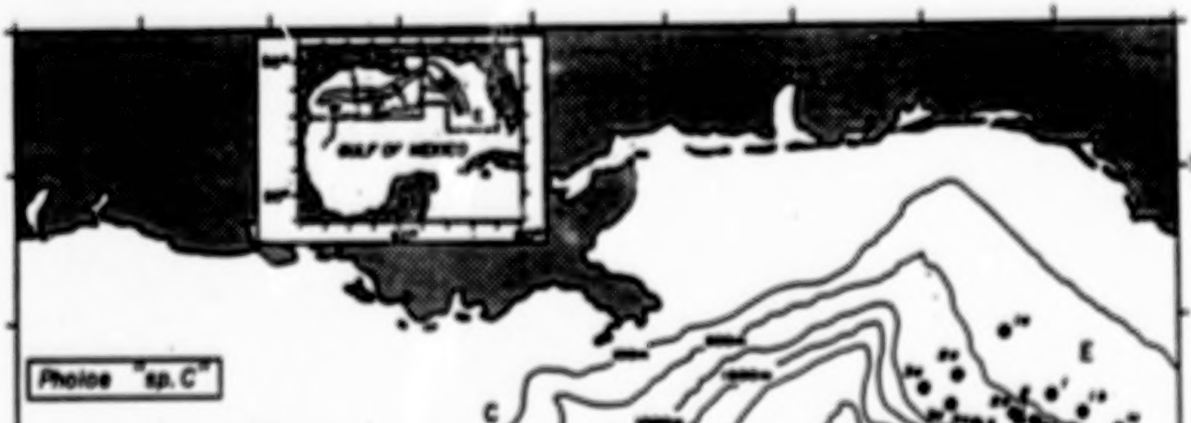
GULF OF MEXICO
Pholoe "sp. C"
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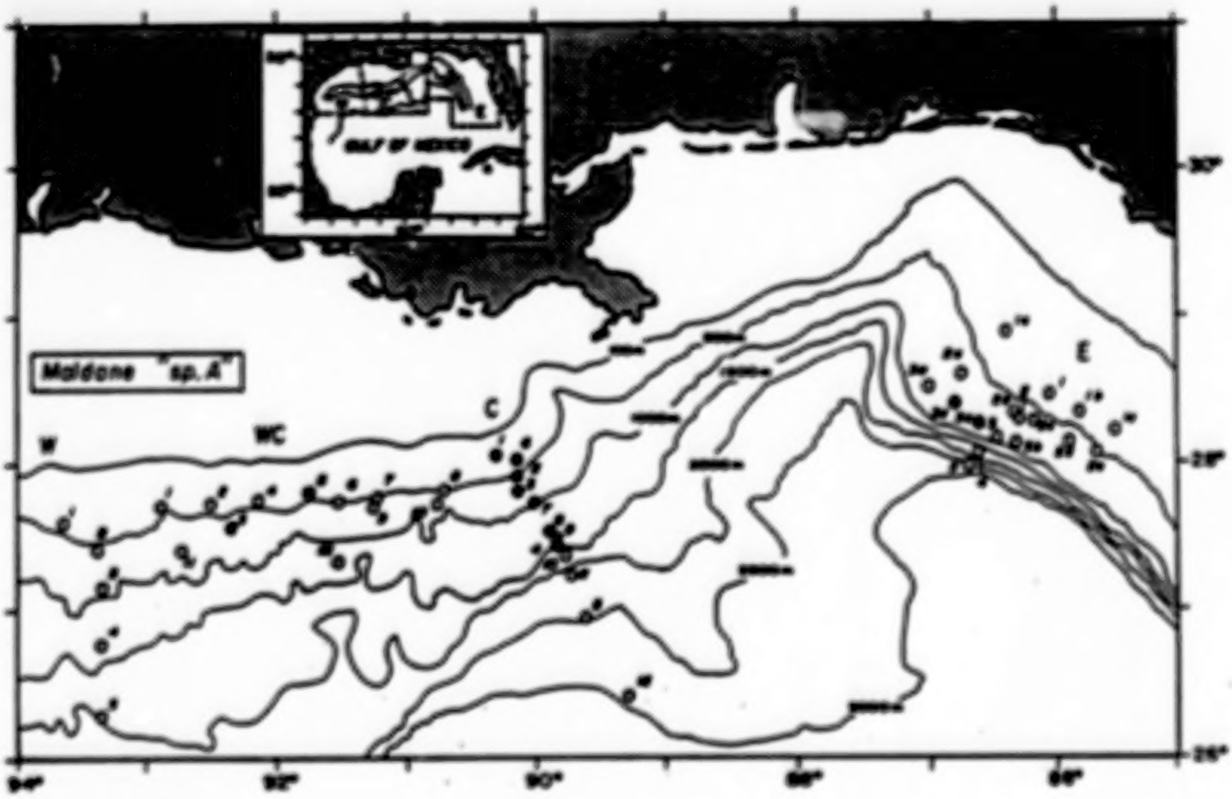
Maldane "sp.A"
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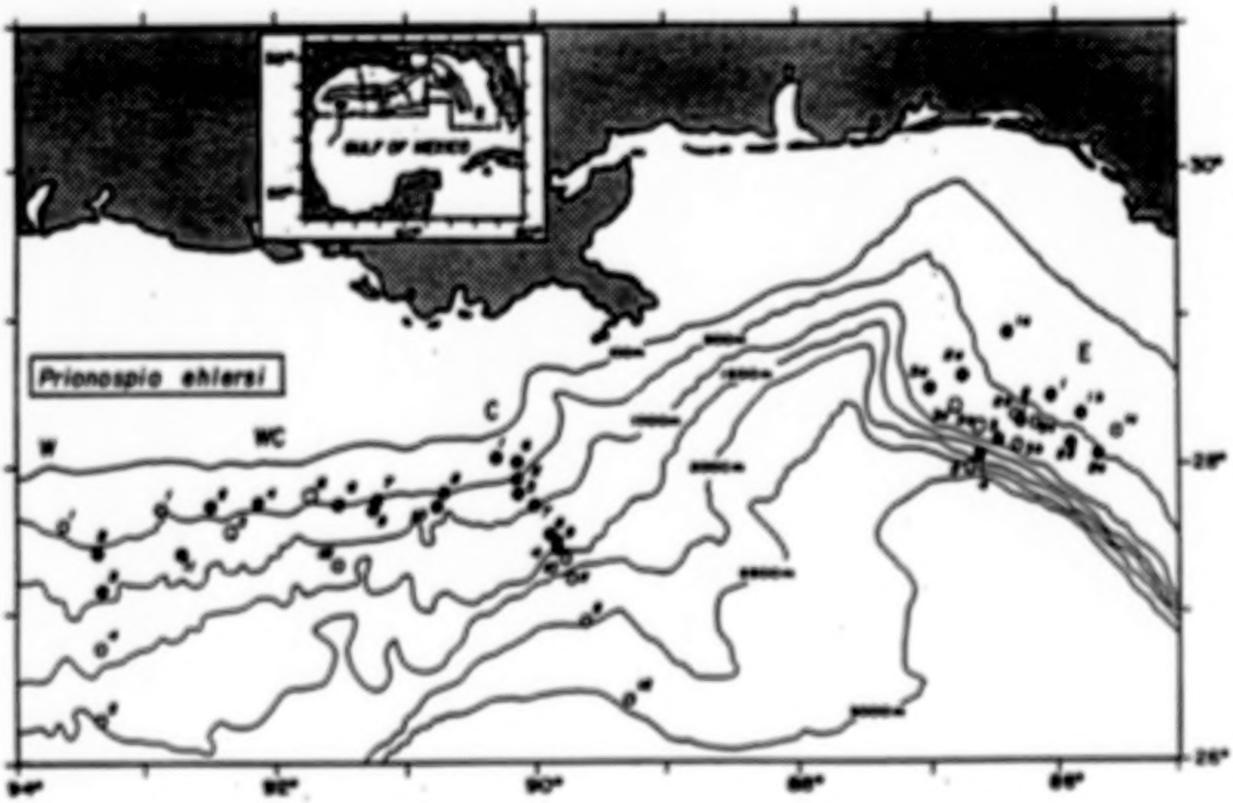
Prionospio ehlersi
GULF OF MEXICO
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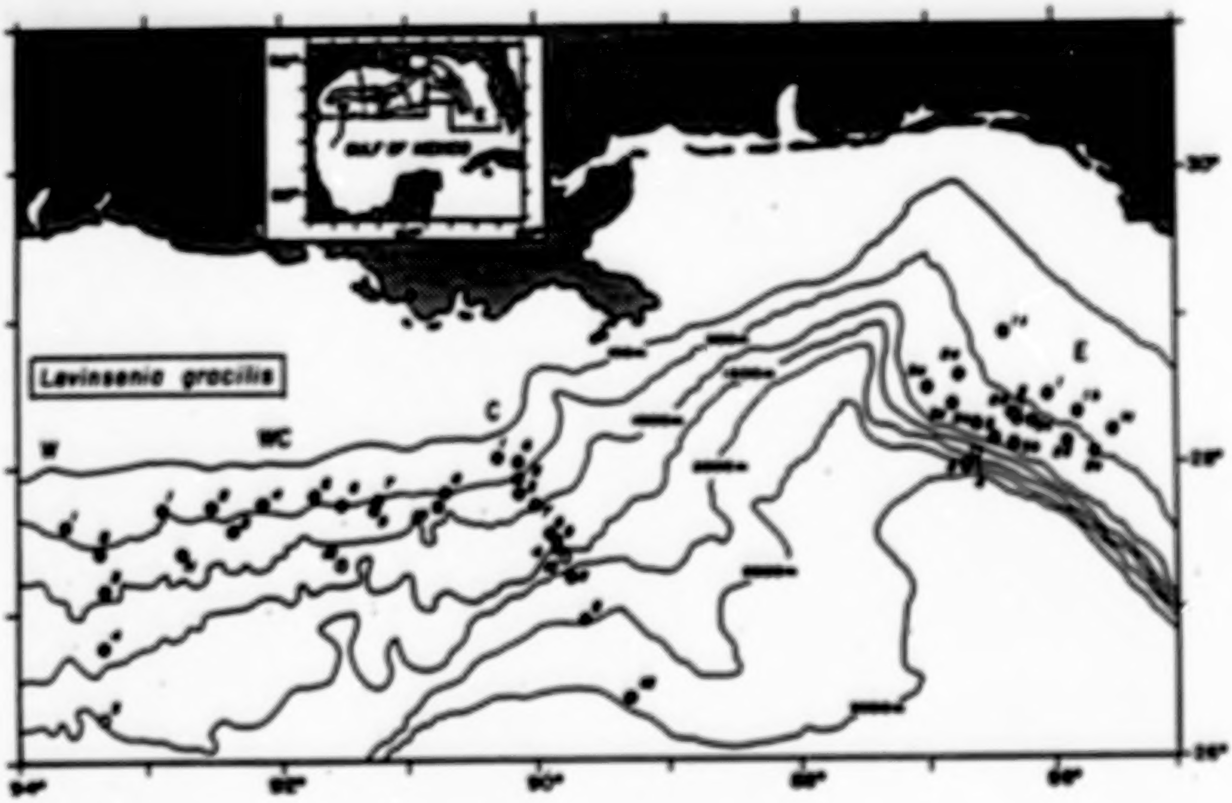
Levinsenia gracilis
GULF OF MEXICO
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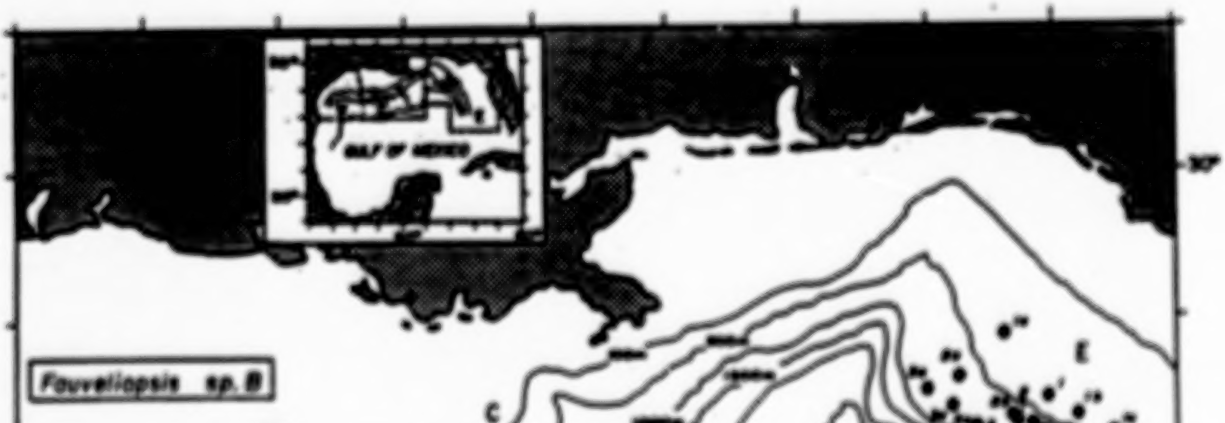
Fauveliopsis sp. B
GULF OF MEXICO
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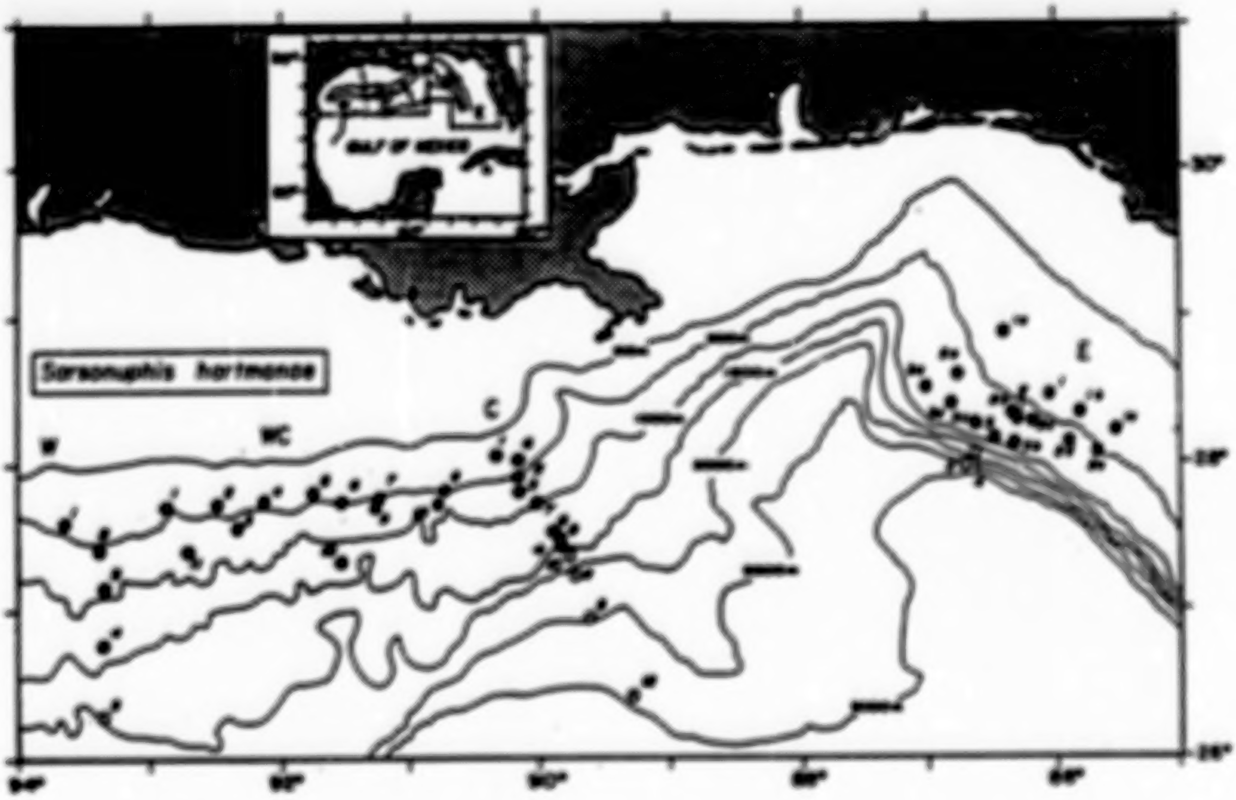
GULF OF MEXICO
Sarsonuphis hartmanae
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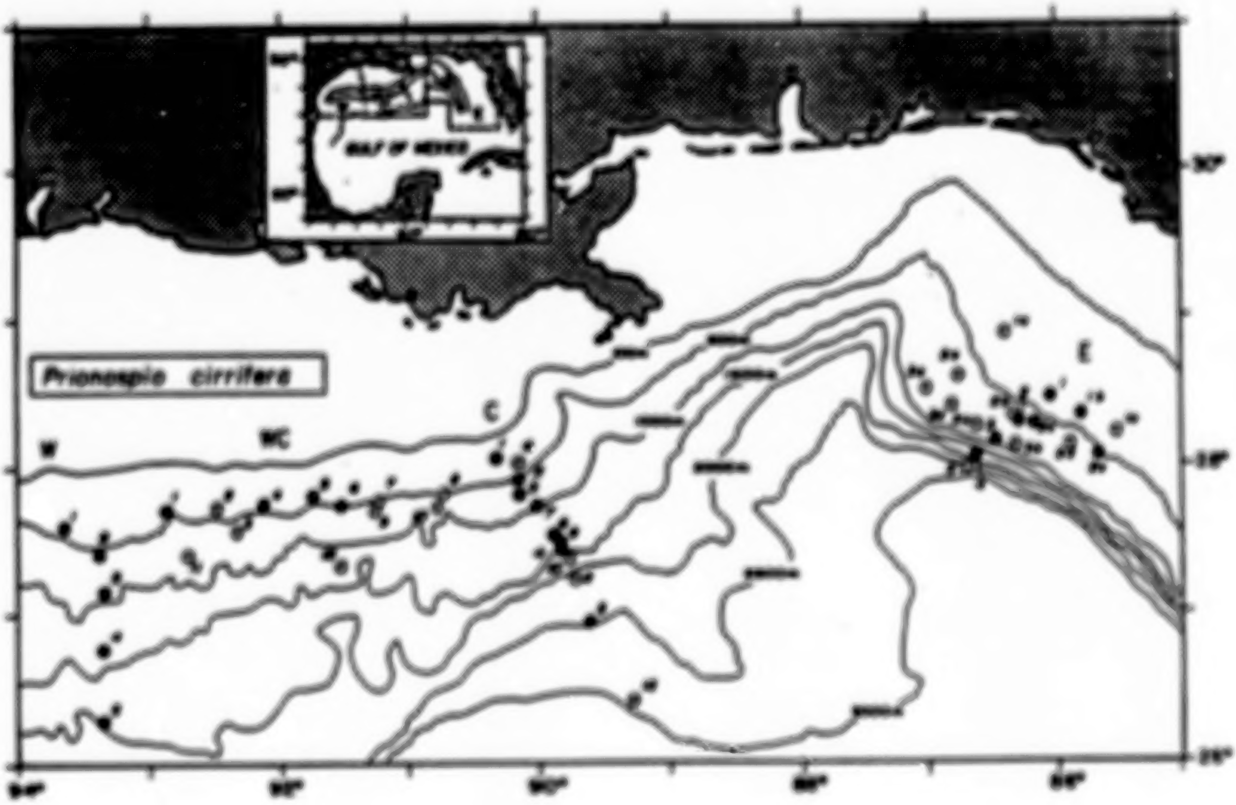
GULF OF MEXICO
Prionospio cirrifera
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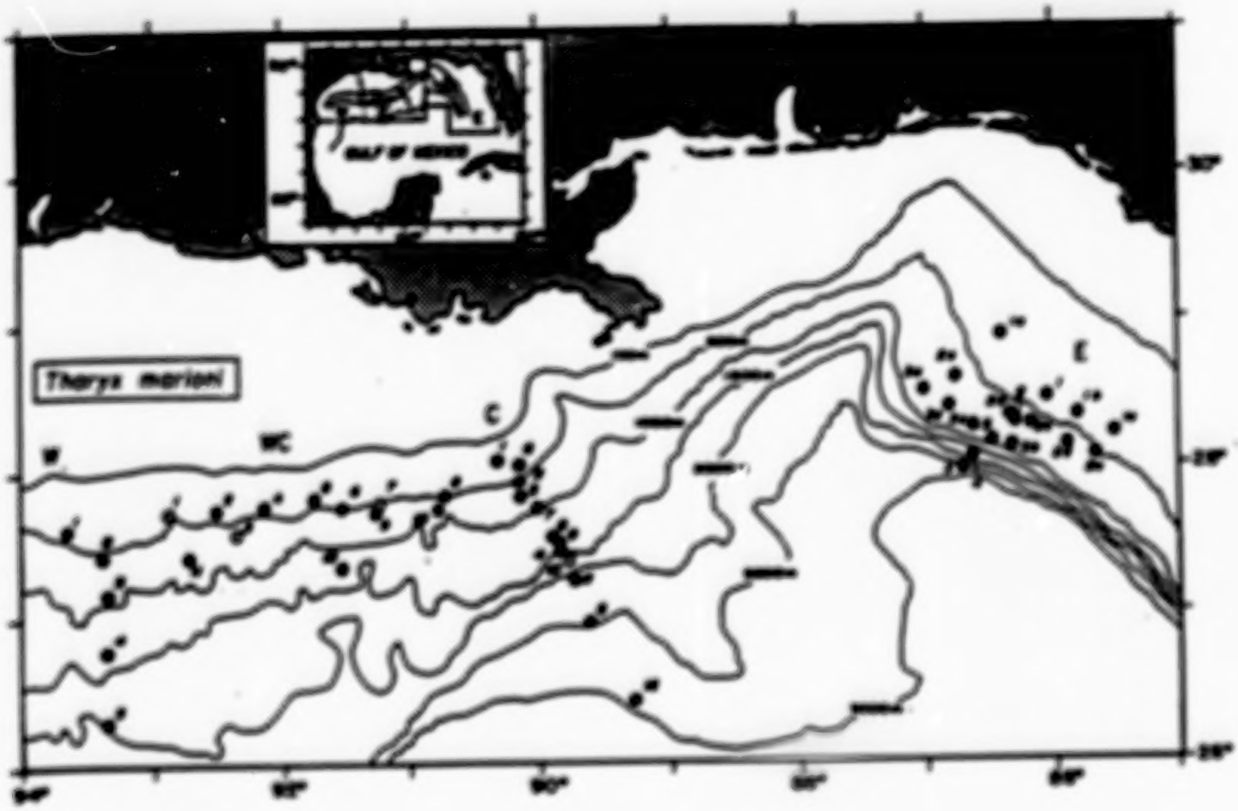
Tharyx marioni
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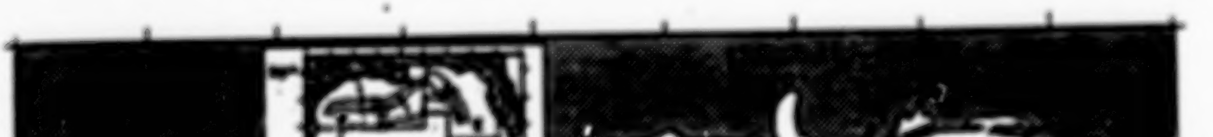
Lumbrinerides dayi
GULF OF MEXICO
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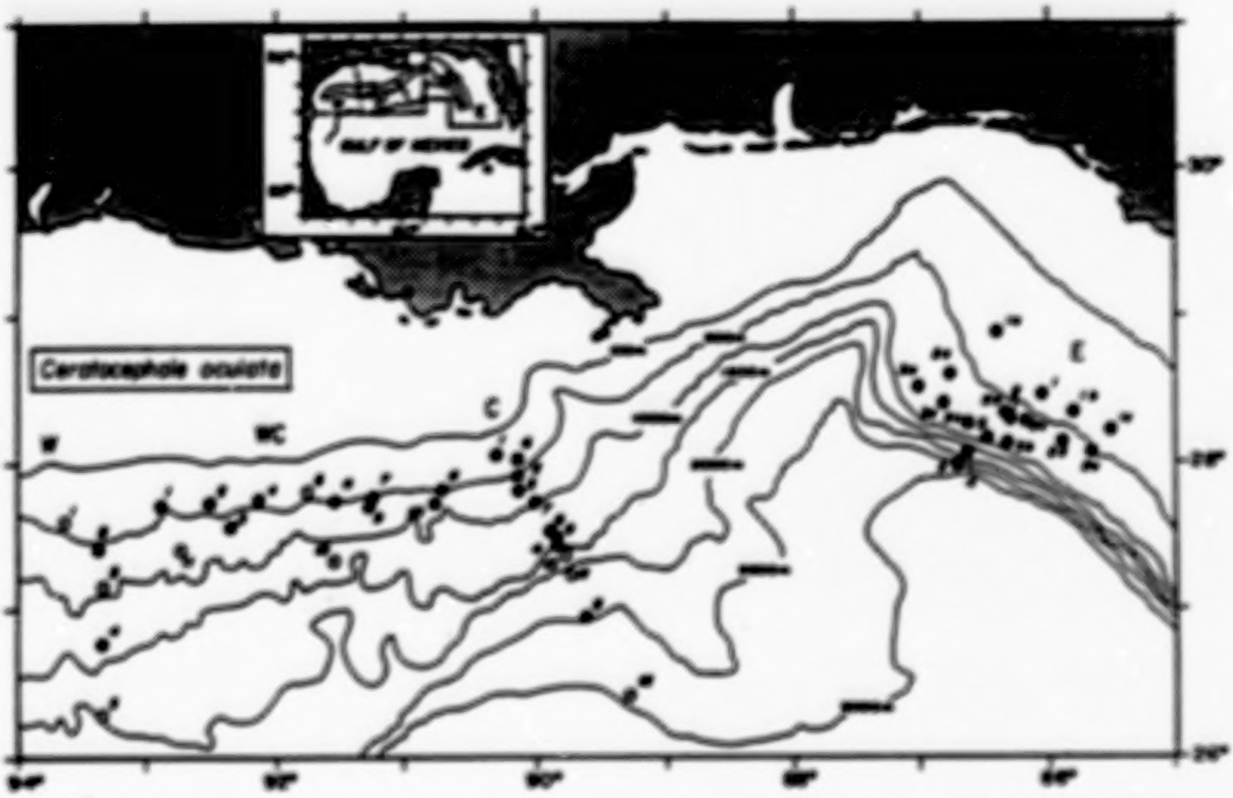
GULF OF MEXICO
Ceratocephale oculata
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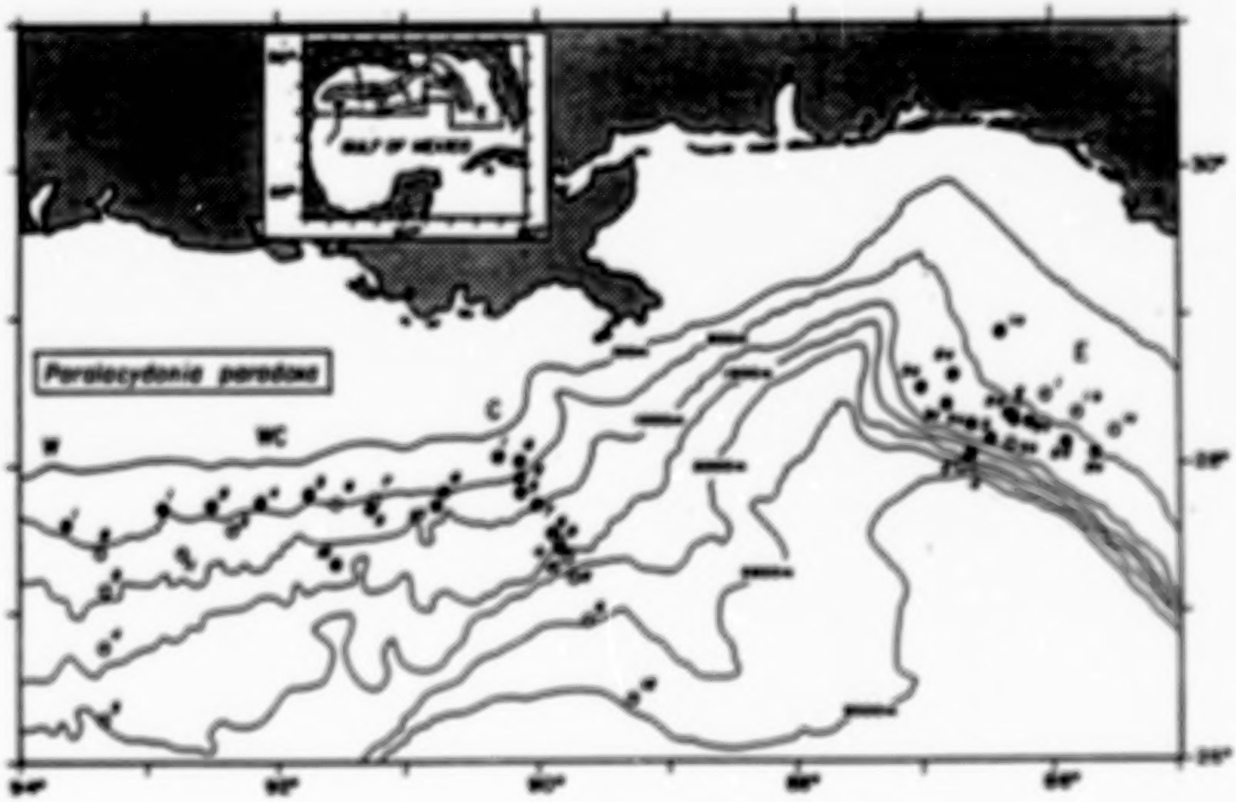
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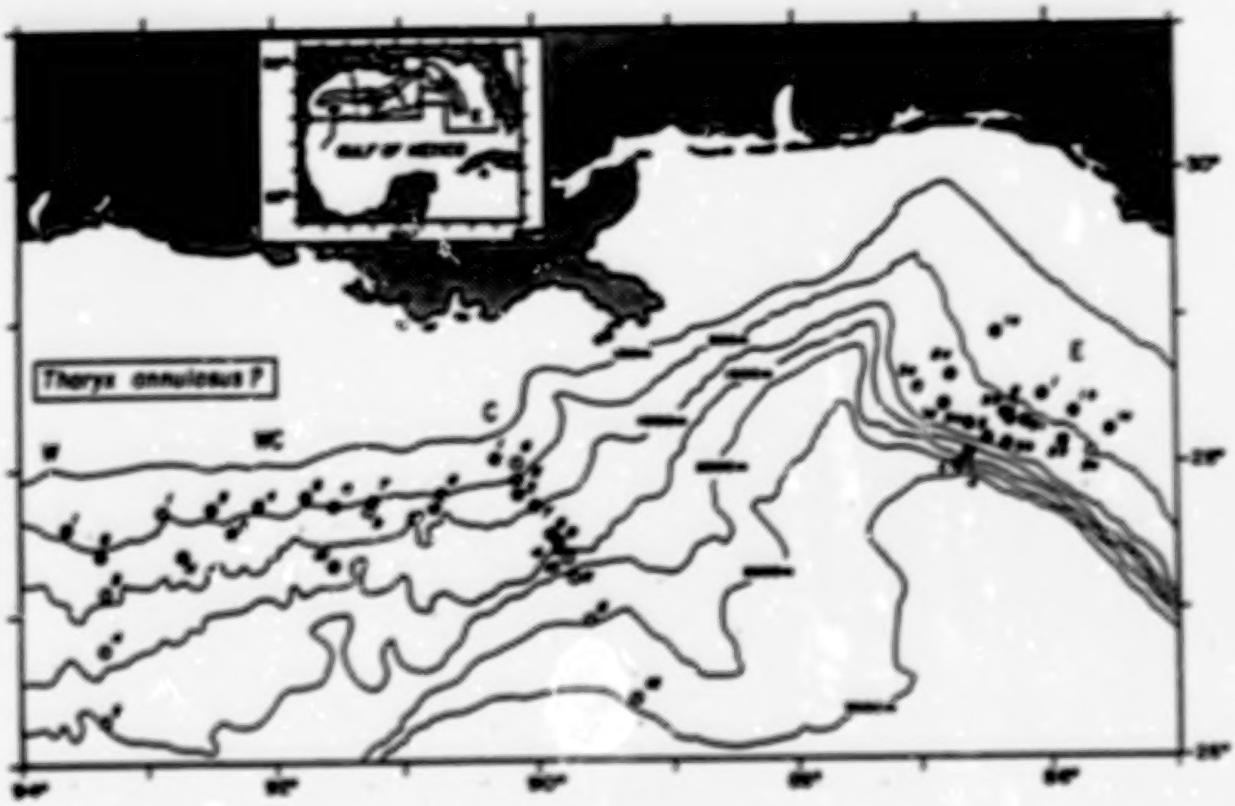
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Tharyx annulosus?
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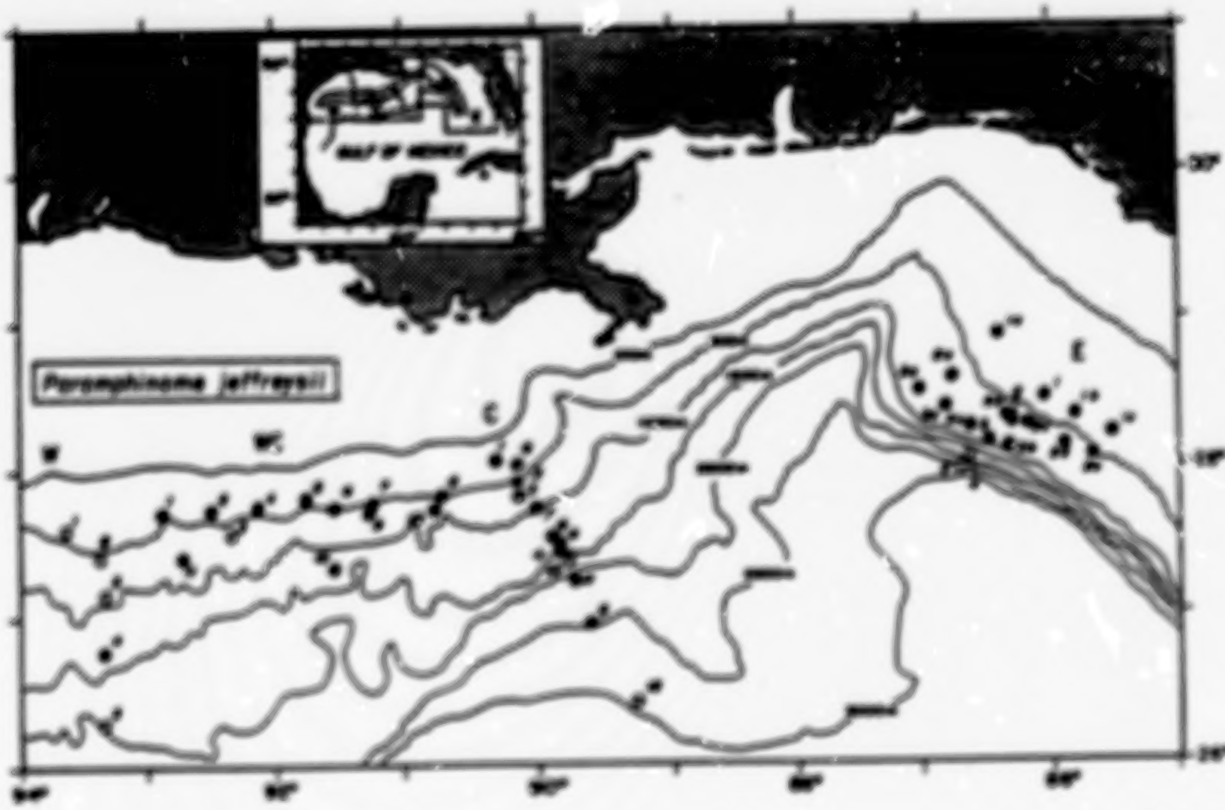
GULF OF MEXICO
Paramphinome jeffreysii
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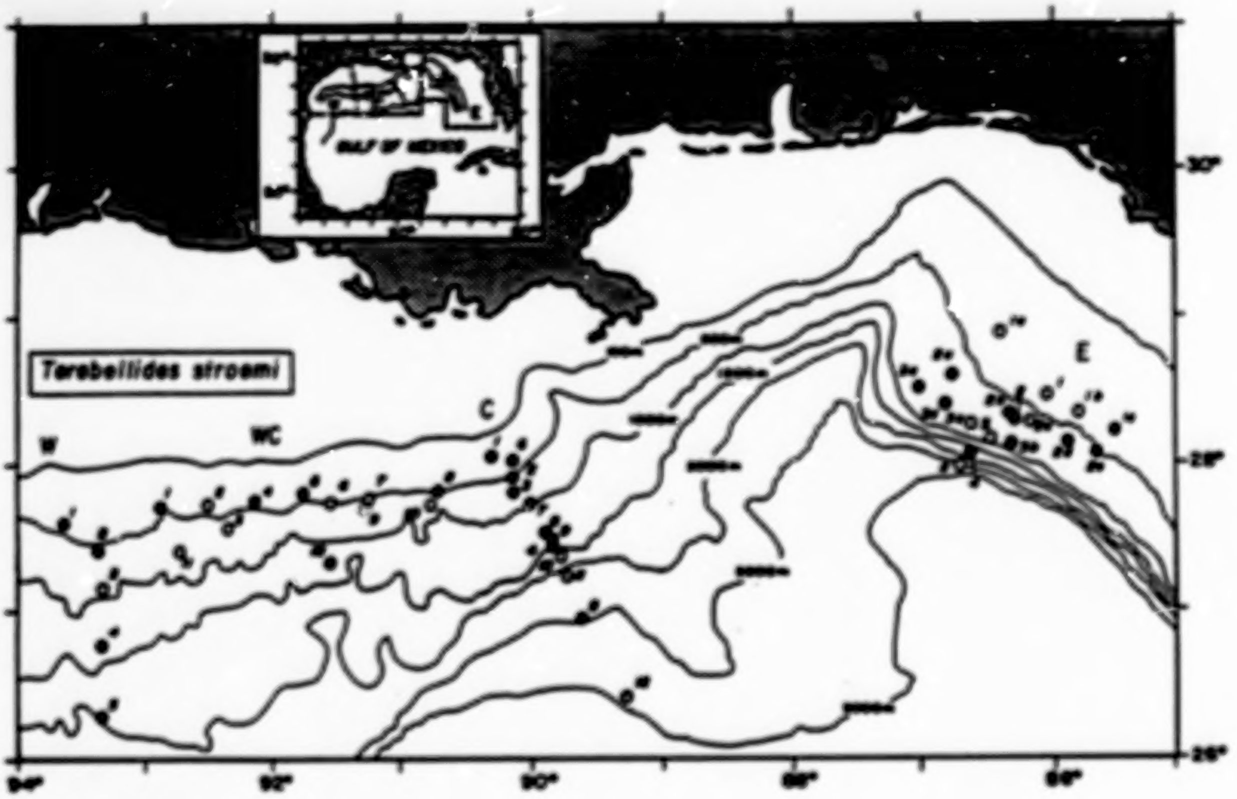
Terebellides stroemi
GULF OF MEXICO
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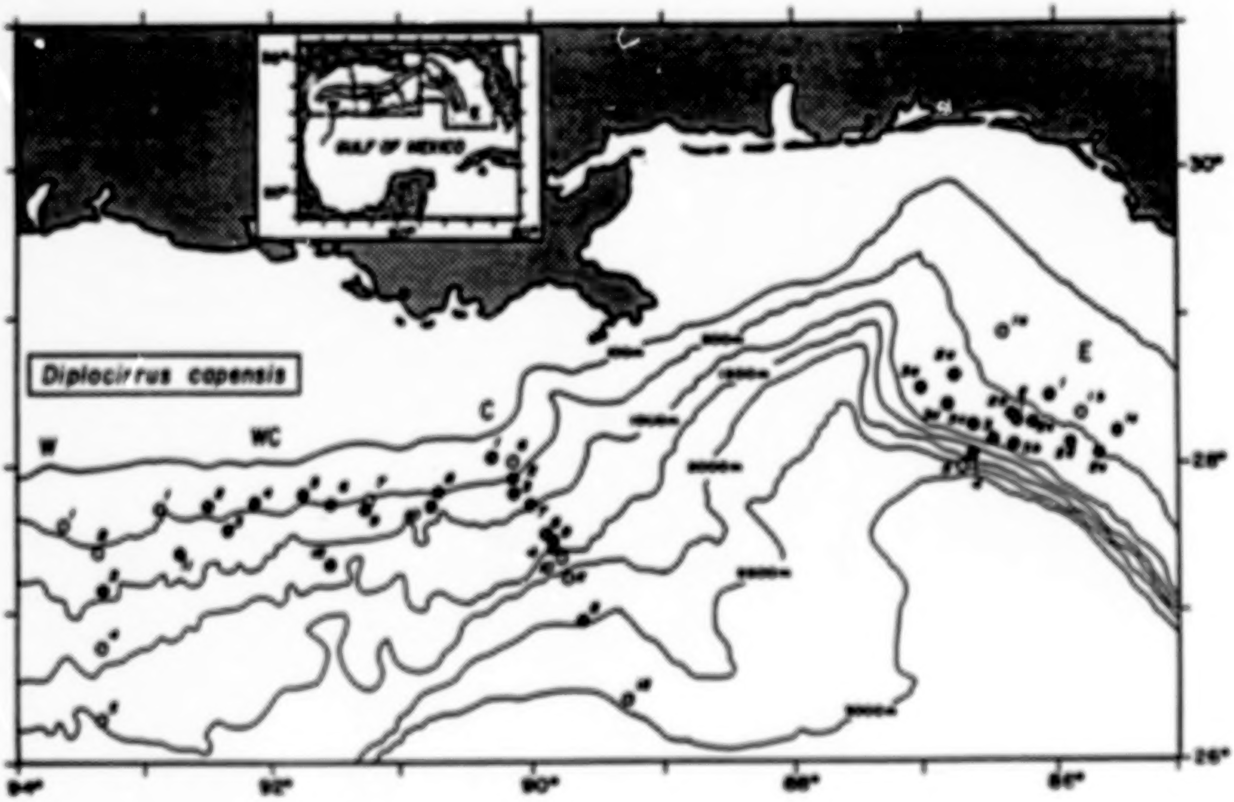
Diplocirrus capensis
GULF OF MEXICO
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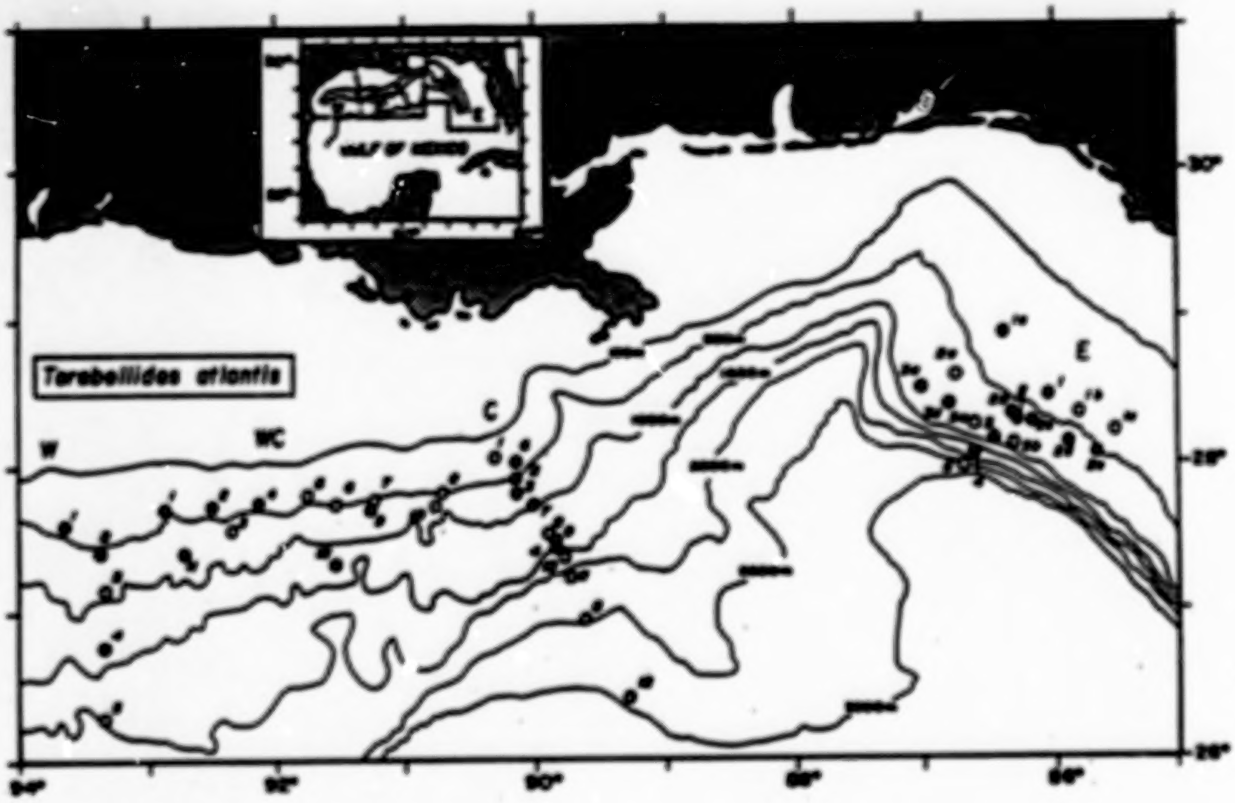
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WC
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GULF OF MEXICO
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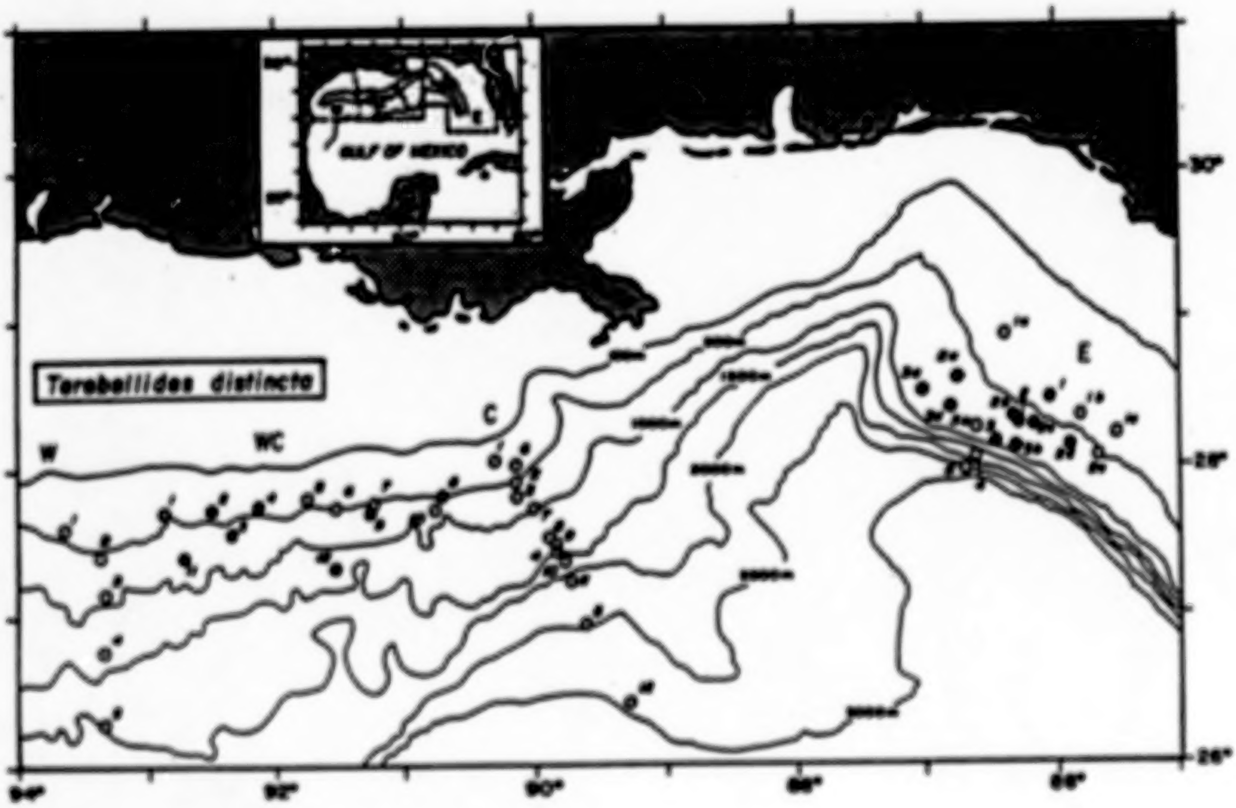
Terebellides distincta
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GULF OF MEXICO
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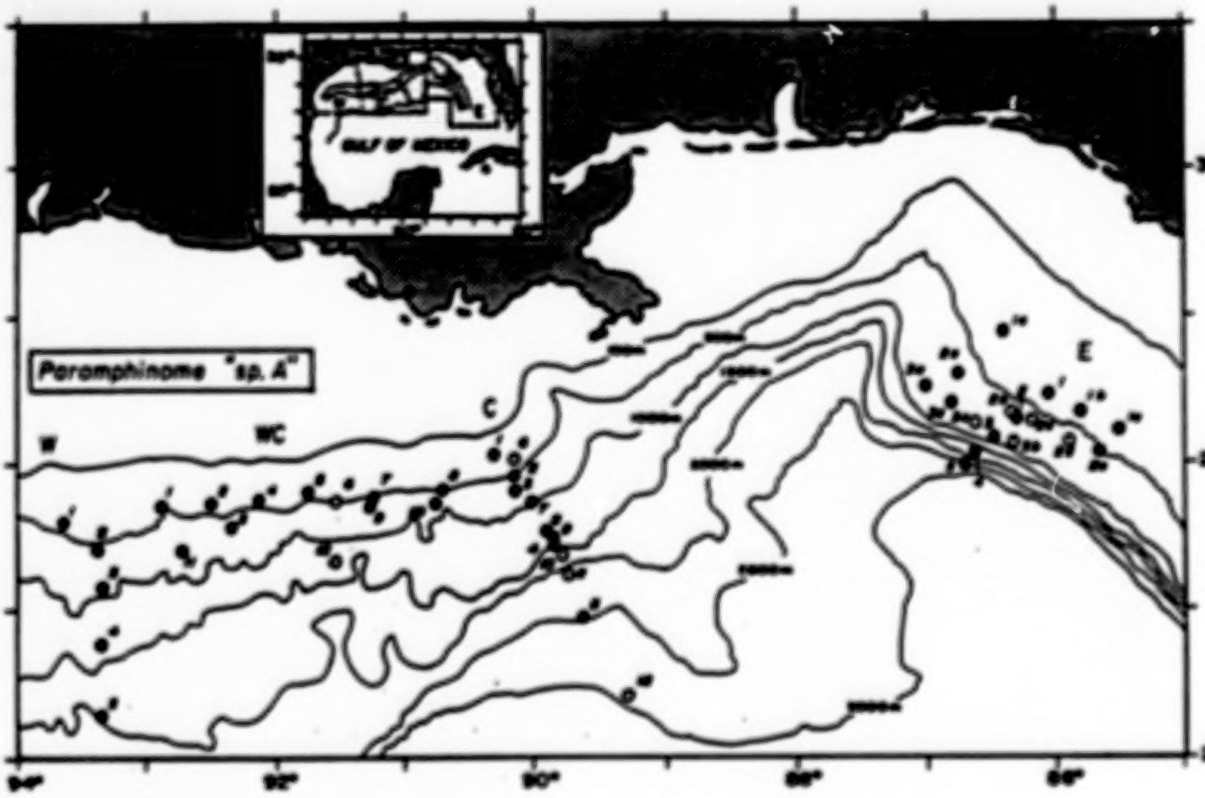
GULF OF MEXICO
Paramphinome "sp. A"
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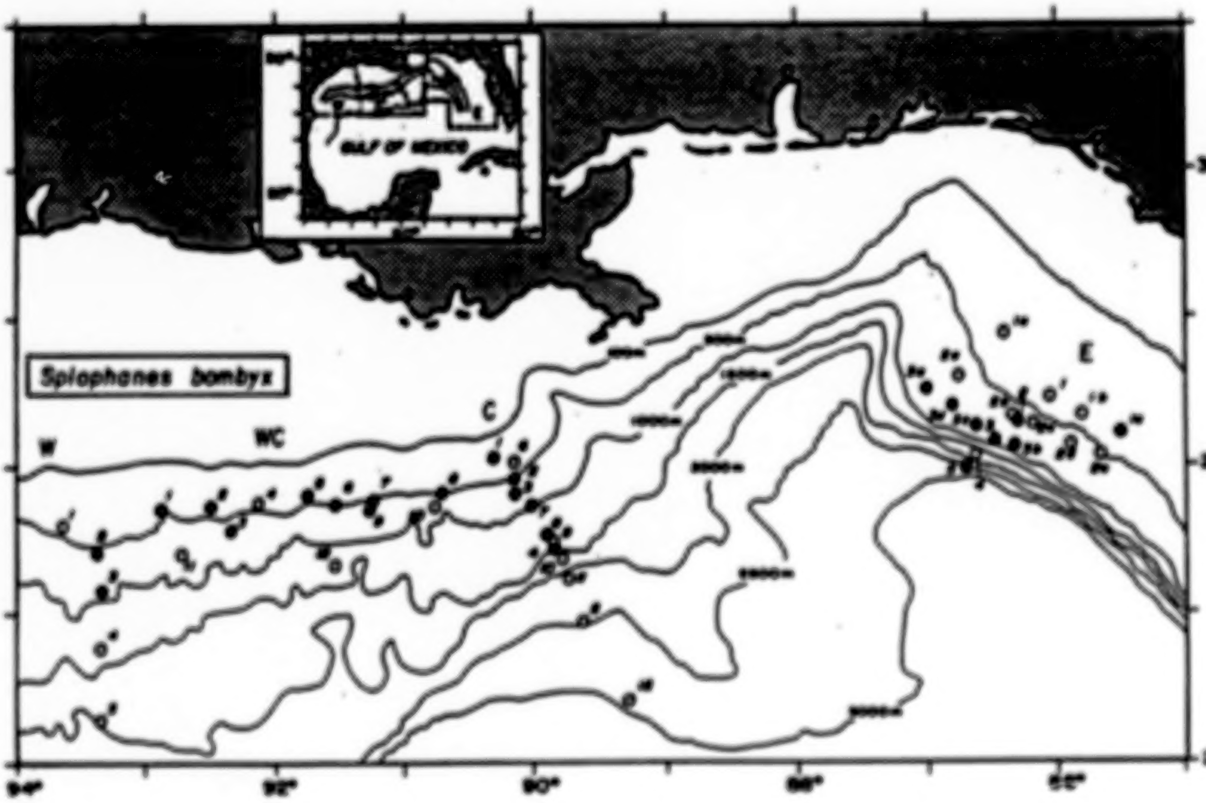
GULF OF MEXICO
Spiophanes bombyx
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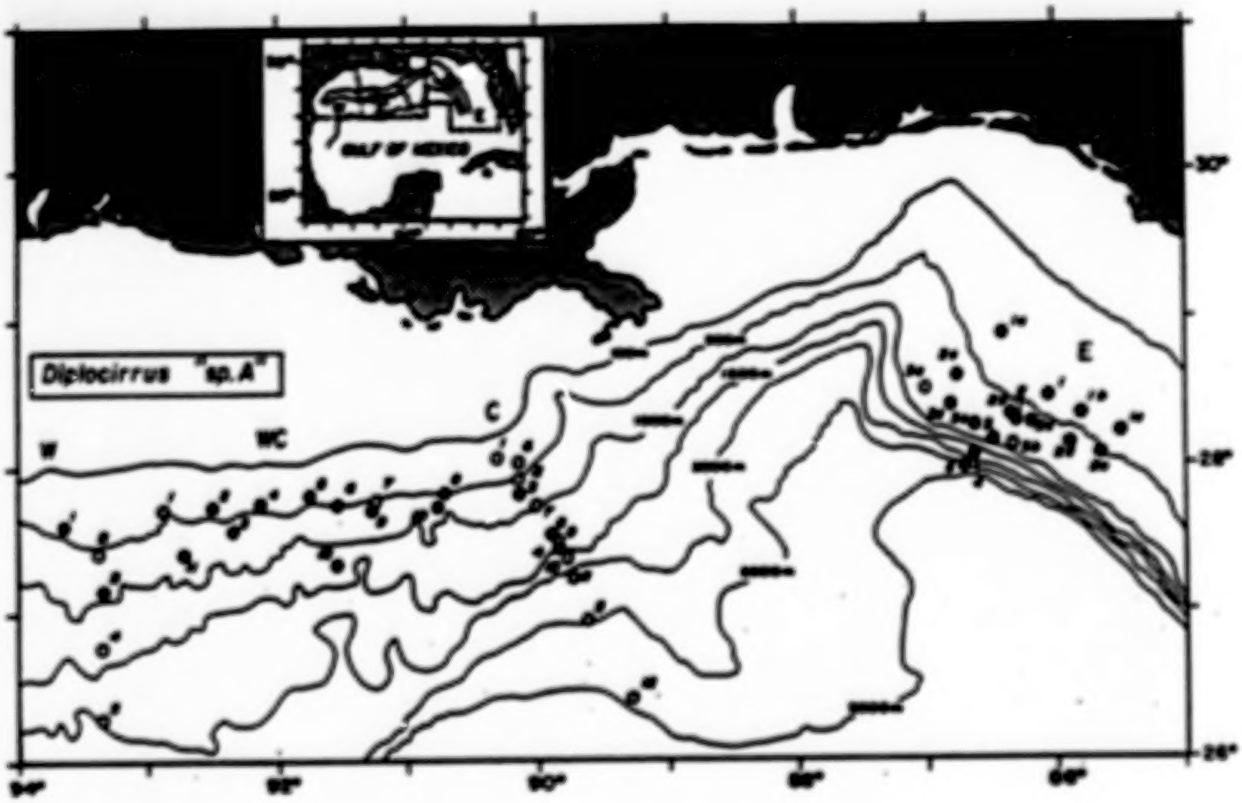
Diplocirrus "sp.A"
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GULF OF MEXICO
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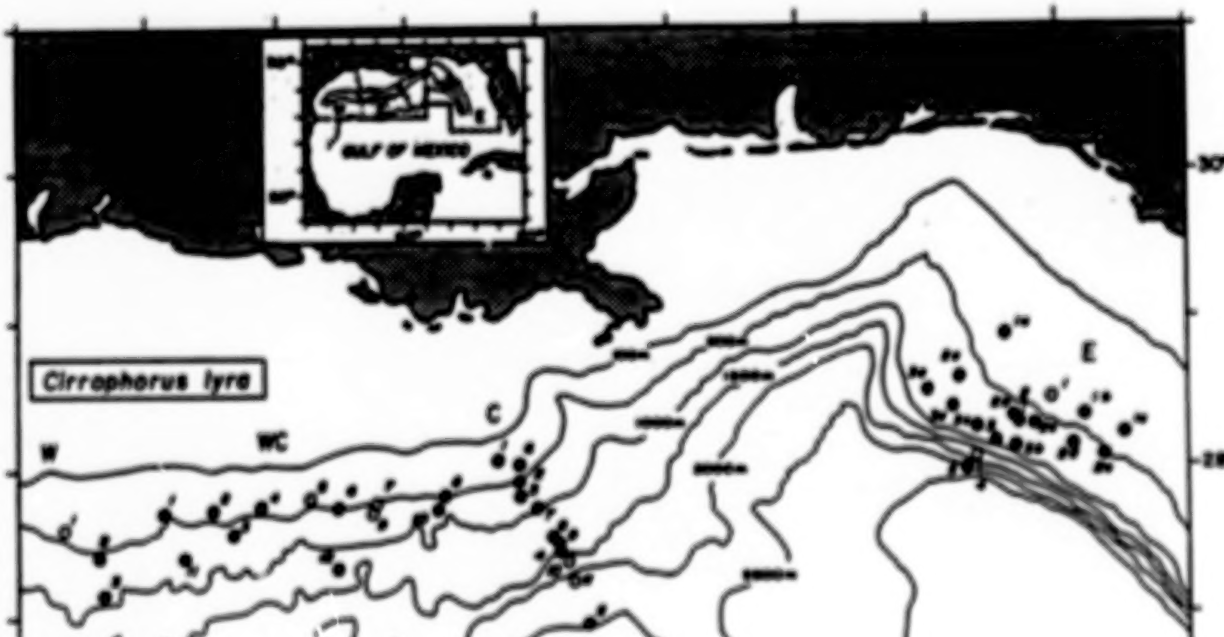
Cirrophorus lyra
W
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GULF OF MEXICO
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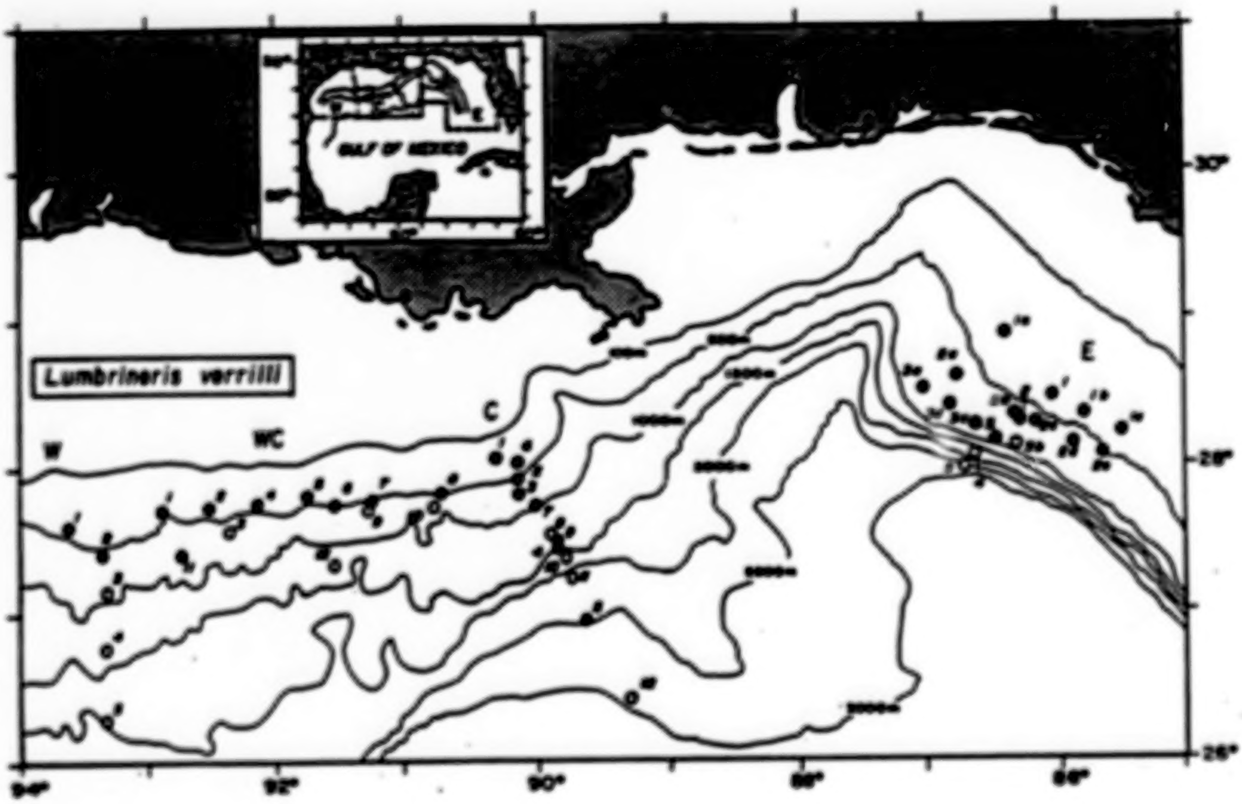
Lumbrineris verrilli
GULF OF MEXICO
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200m
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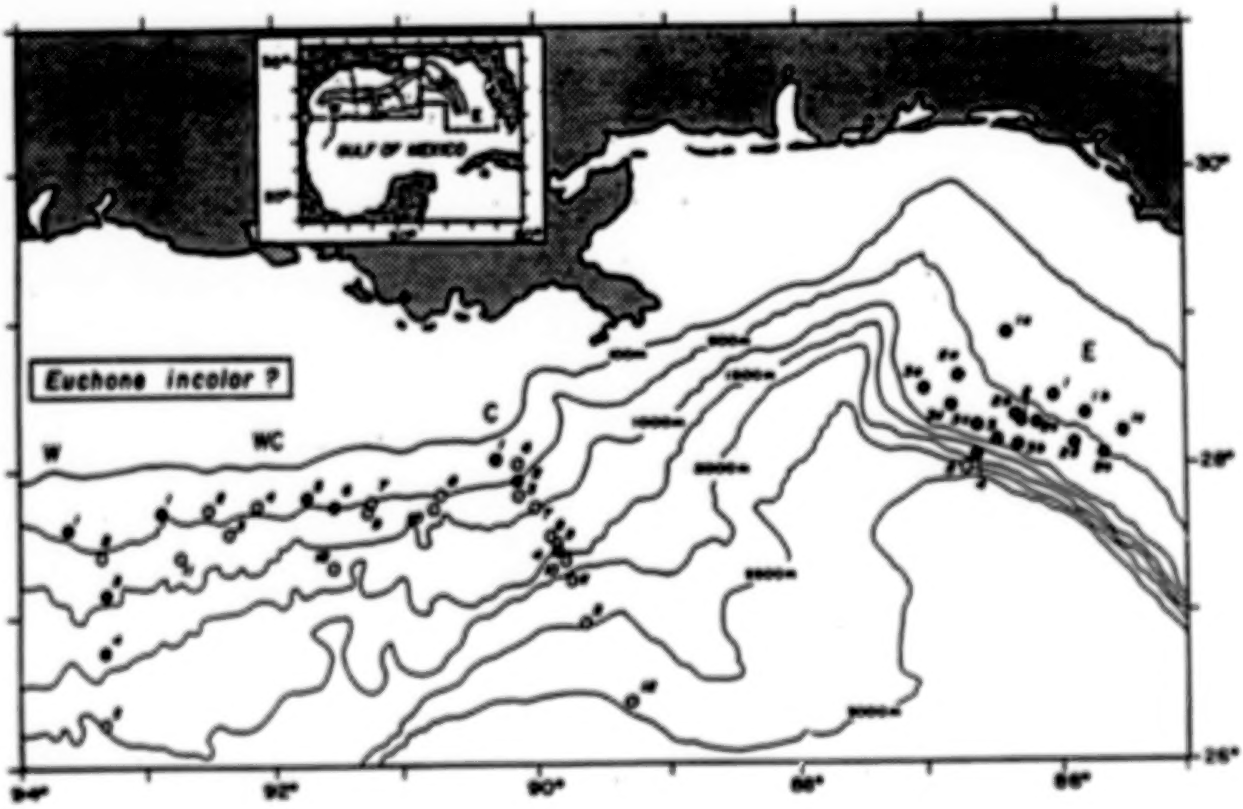
Euchone incolor ?
GULF OF MEXICO
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500m
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3000m
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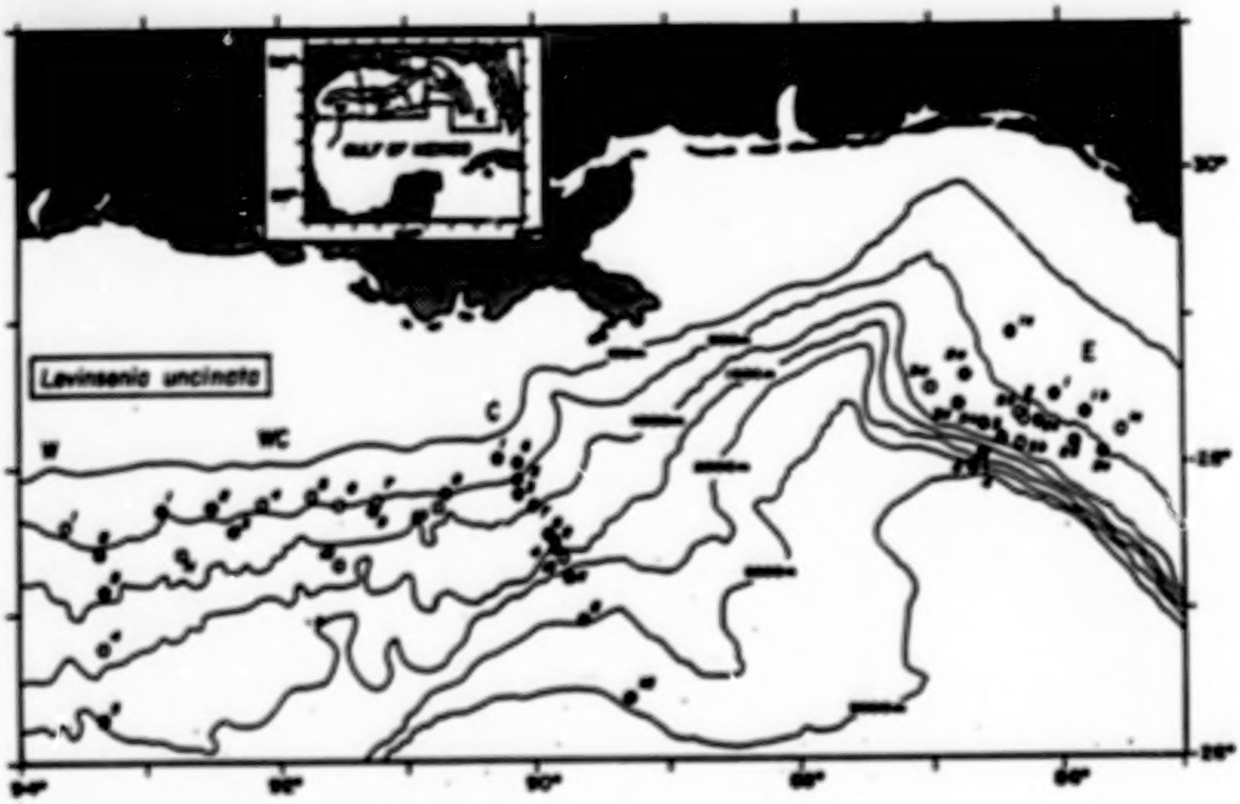
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Levinsenia uncinata
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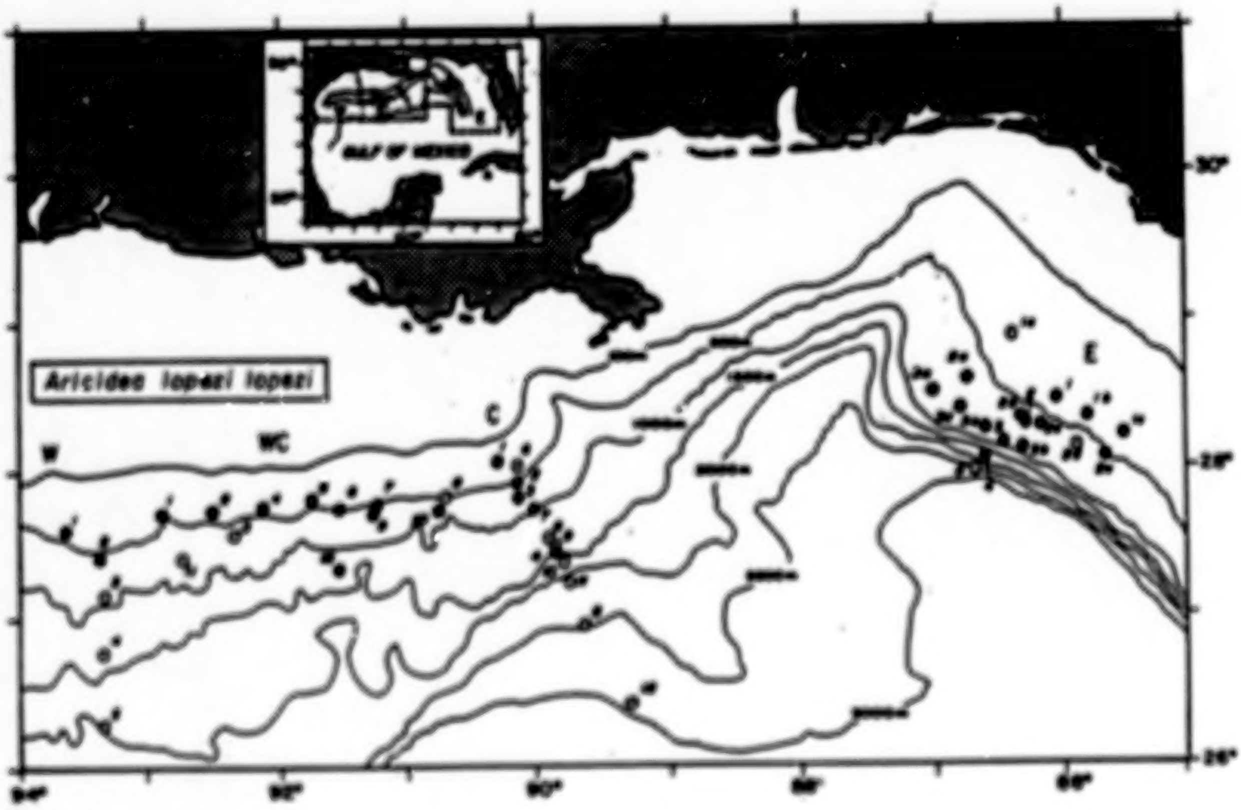
GULF OF MEXICO
Aricidea lopezi lopezi
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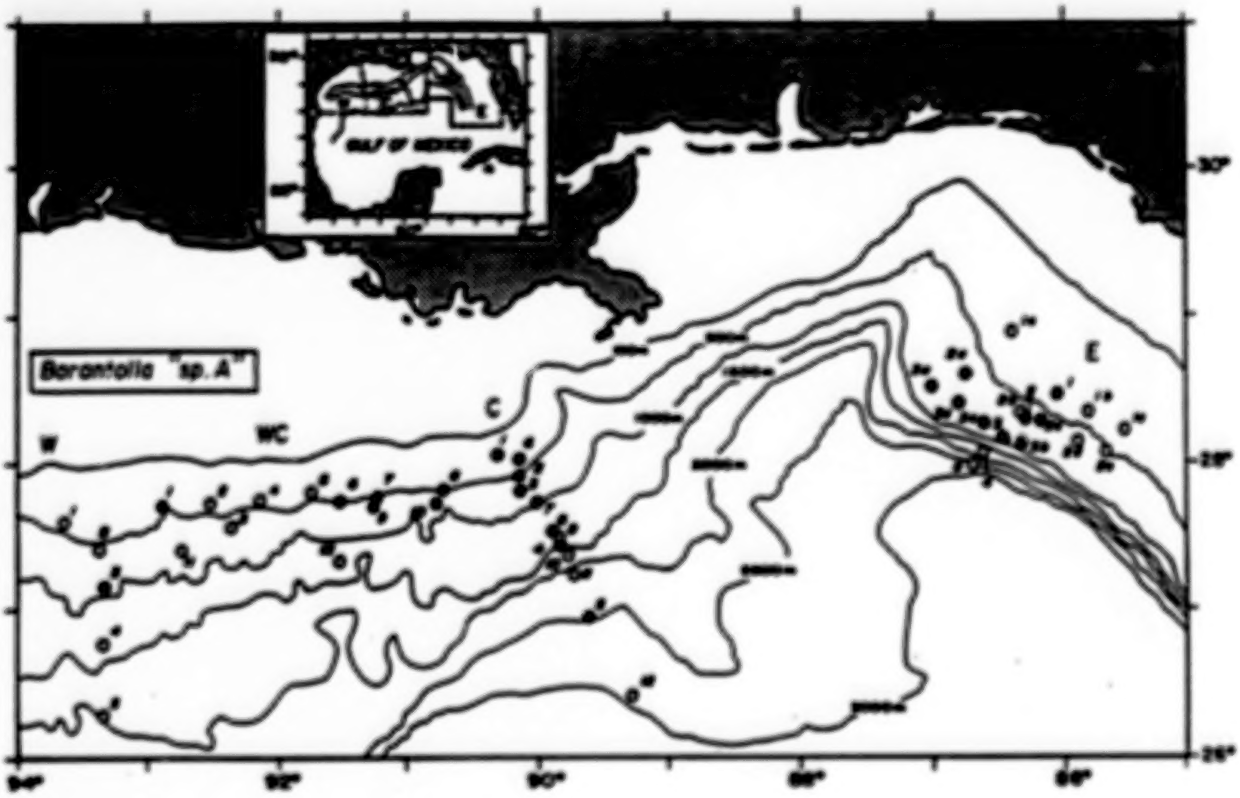
GULF OF MEXICO
Barantolla "sp.A"
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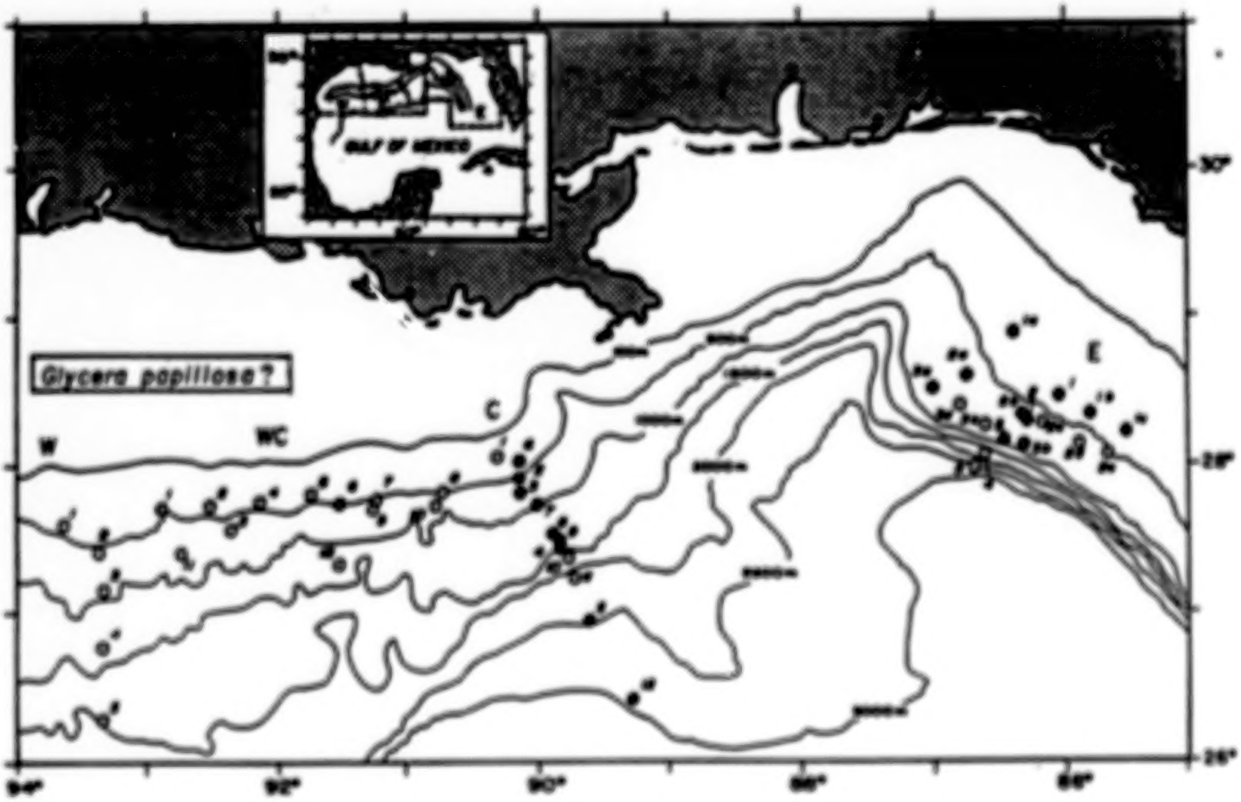
GULF OF MEXICO
Glycera papillosa?
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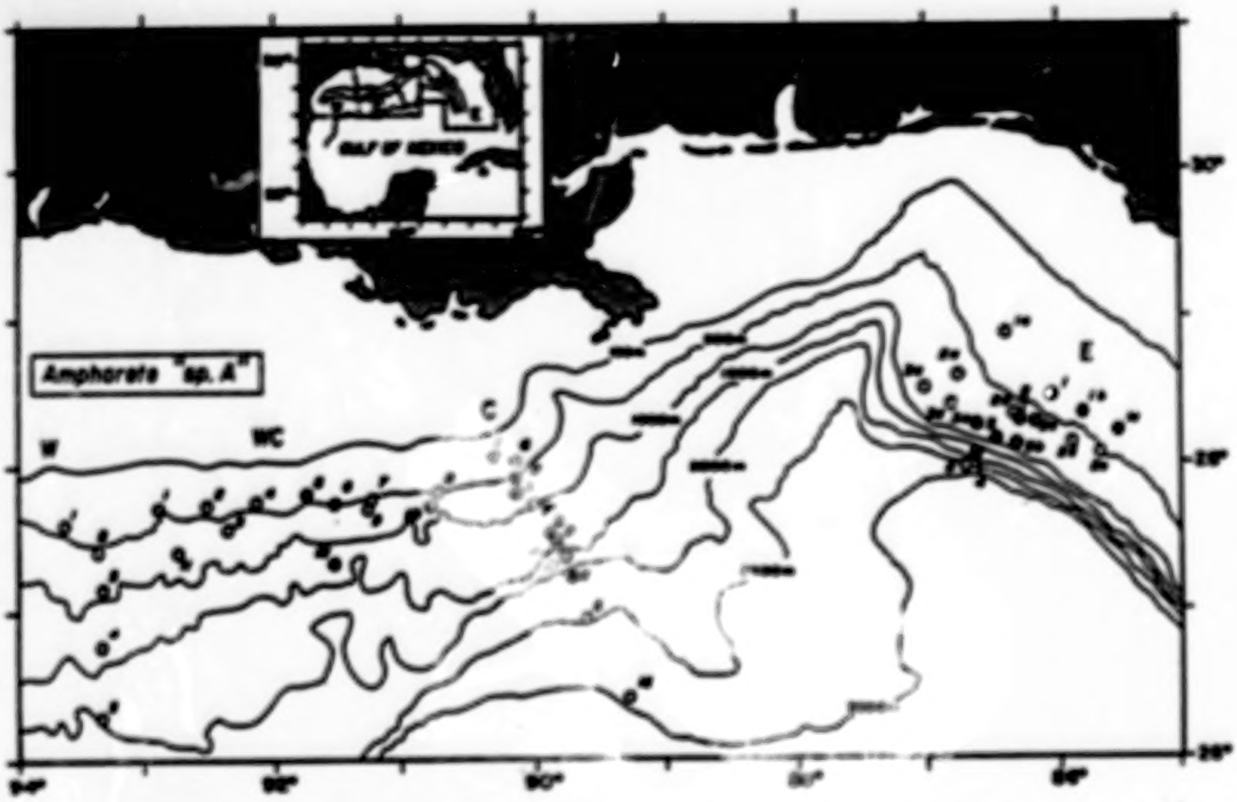
Ampharete "sp. A"
GULF OF MEXICO
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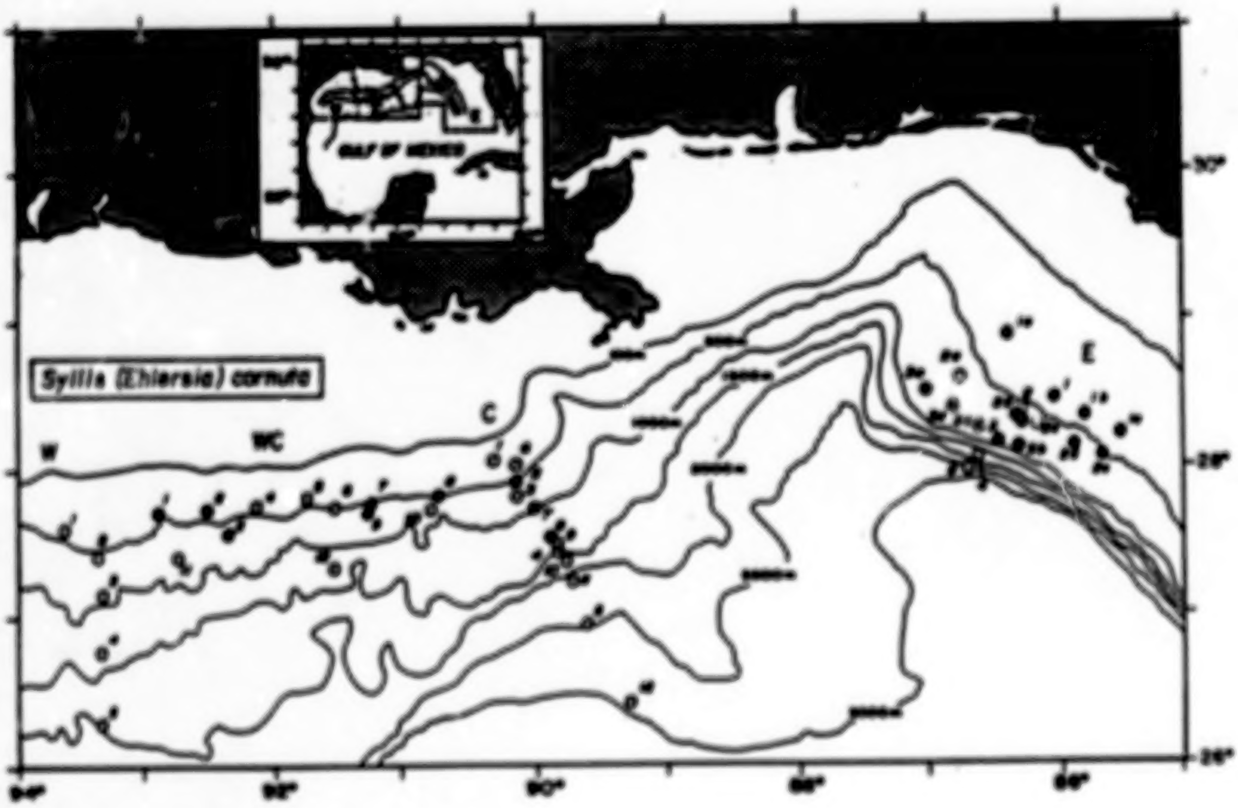
Syllis (Ehlersia) cornuta
GULF OF MEXICO
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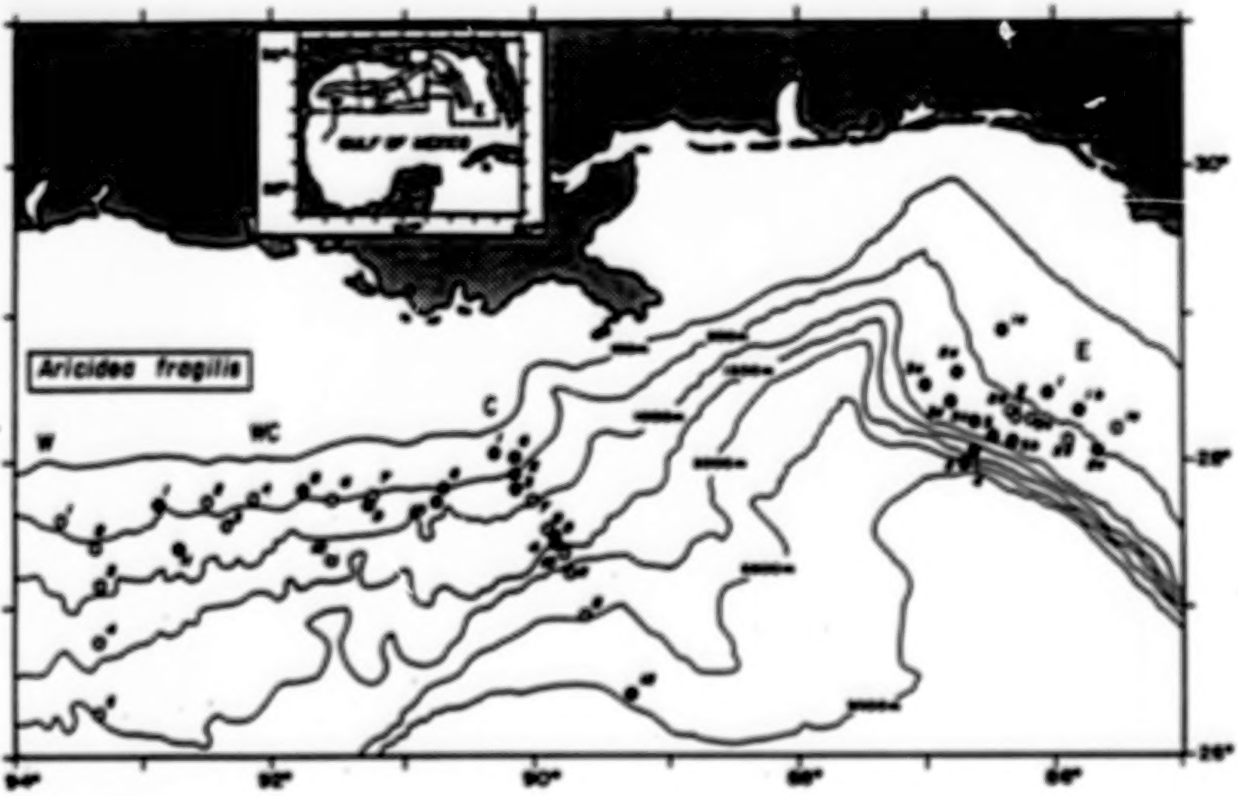
Aricidea fragilis
GULF OF MEXICO
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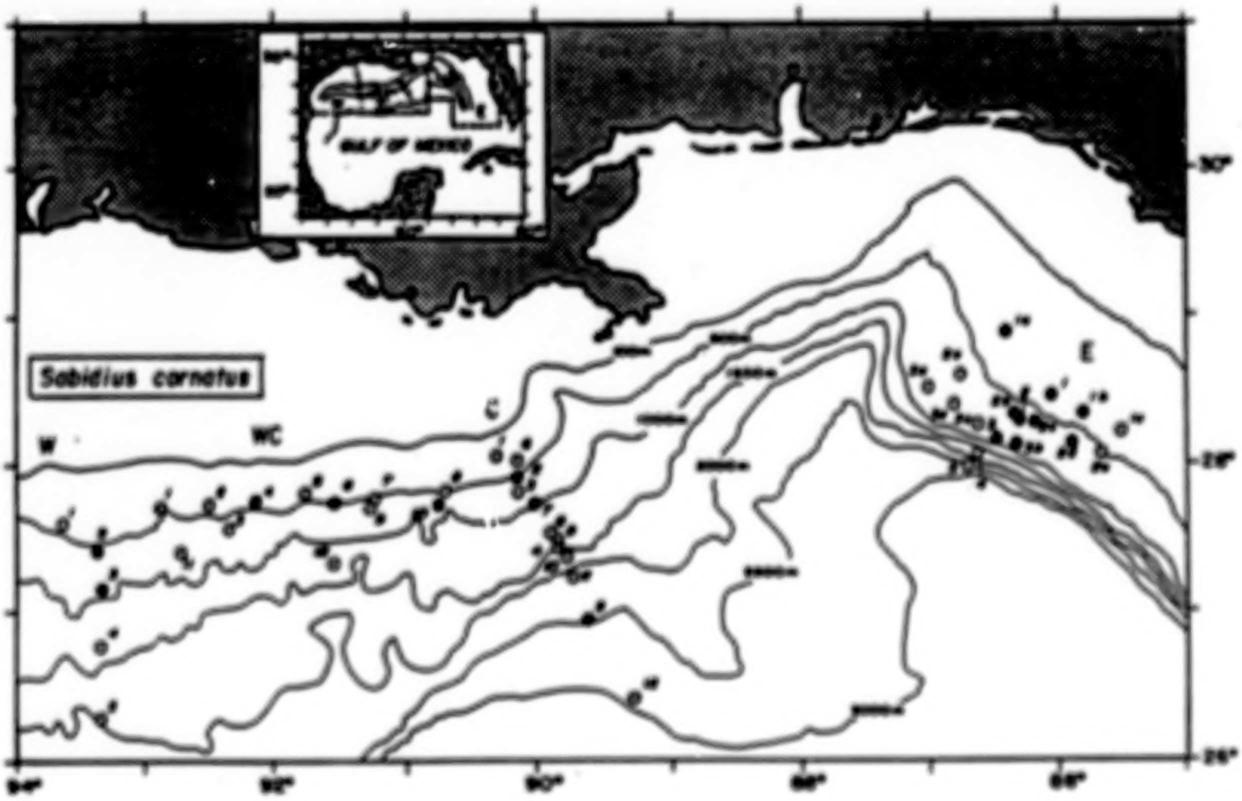
Sabidius cornatus
GULF OF MEXICO
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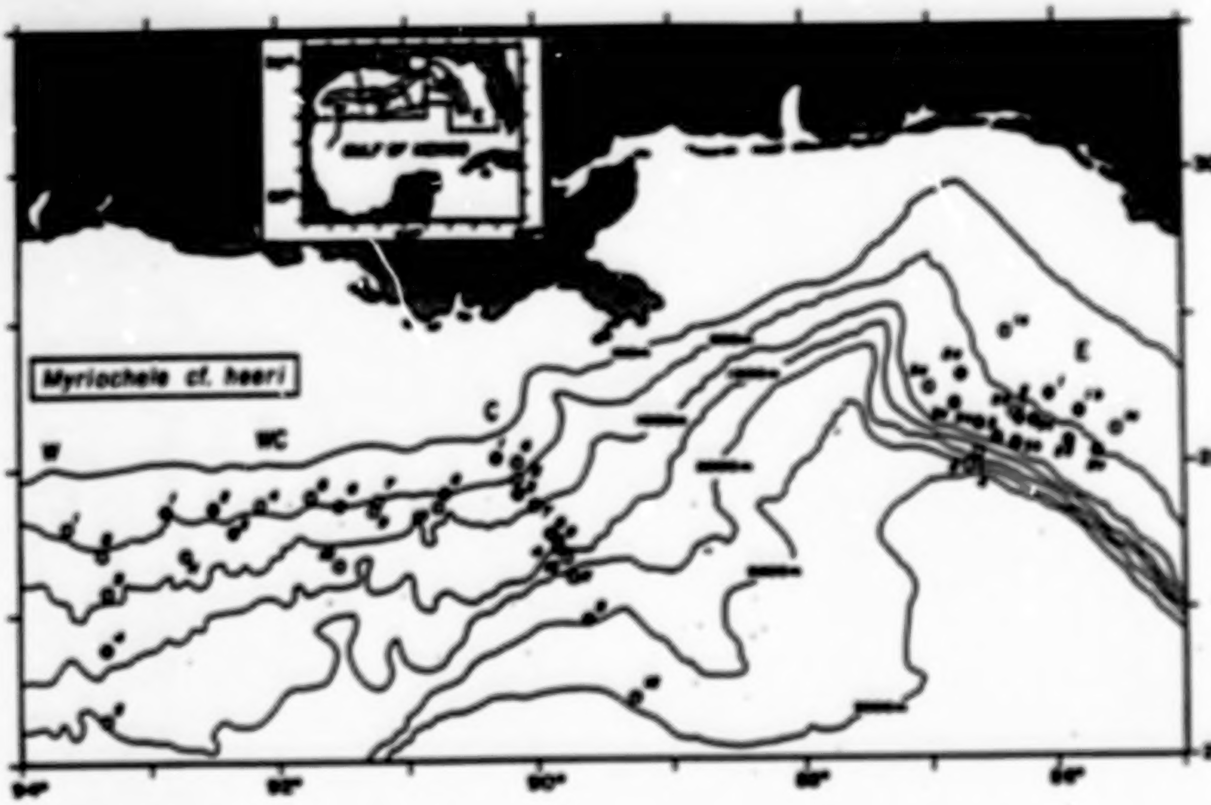
Myriochele cf. heeri
GULF OF MEXICO
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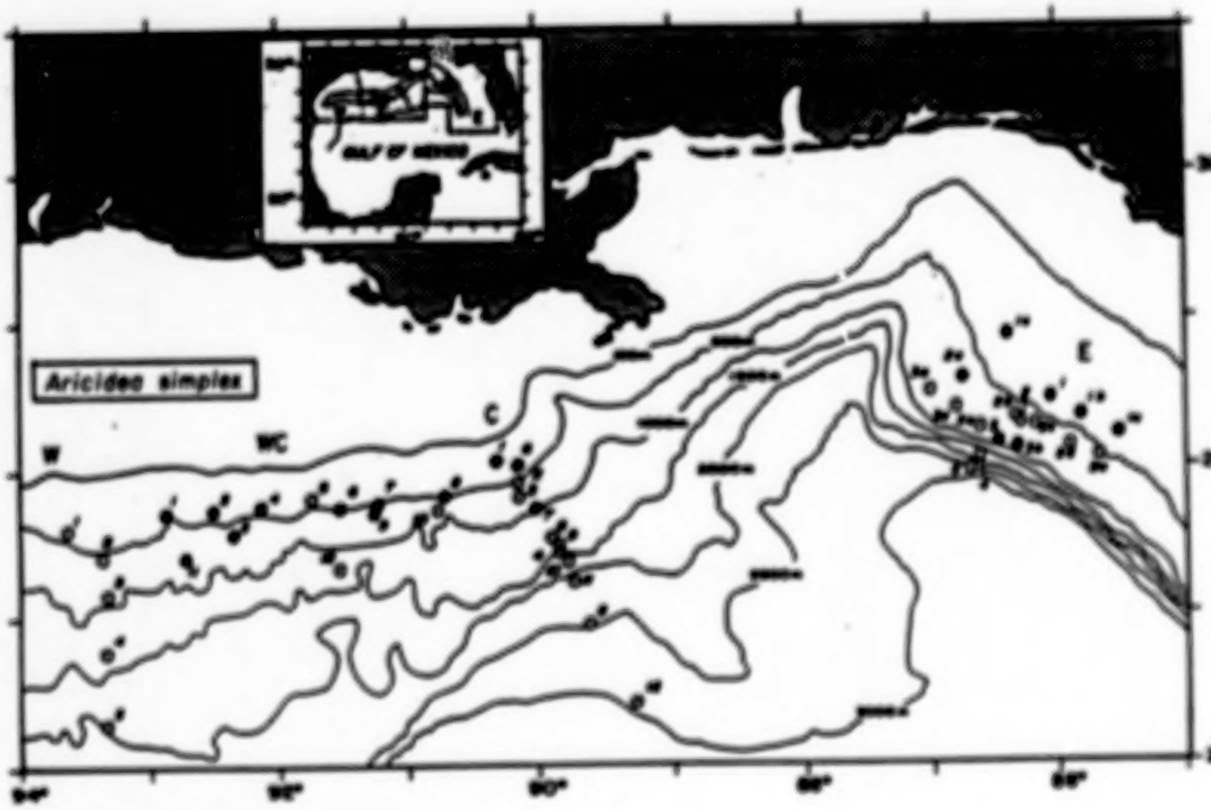
Aricidea simplex
GULF OF MEXICO
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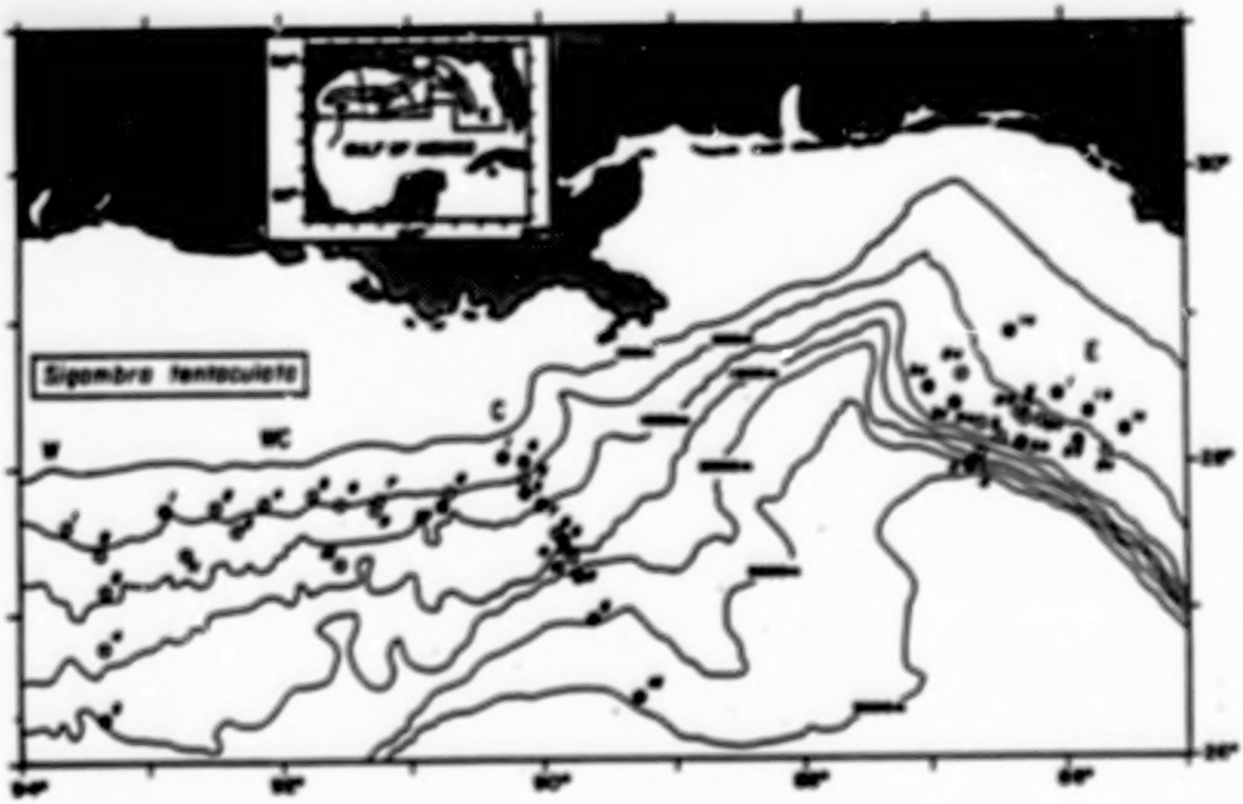
GULF OF MEXICO
Sigambra tentaculata
W
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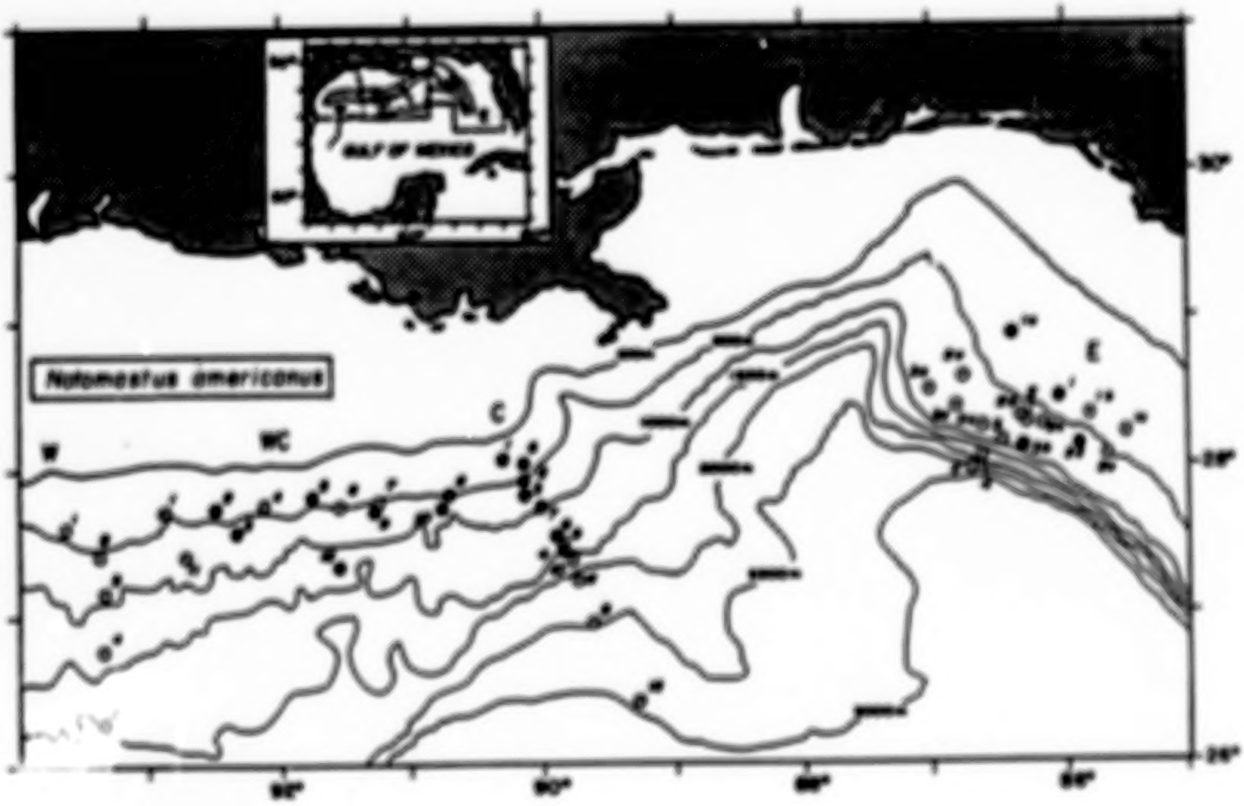
GULF OF MEXICO
Notomastus americanus
W
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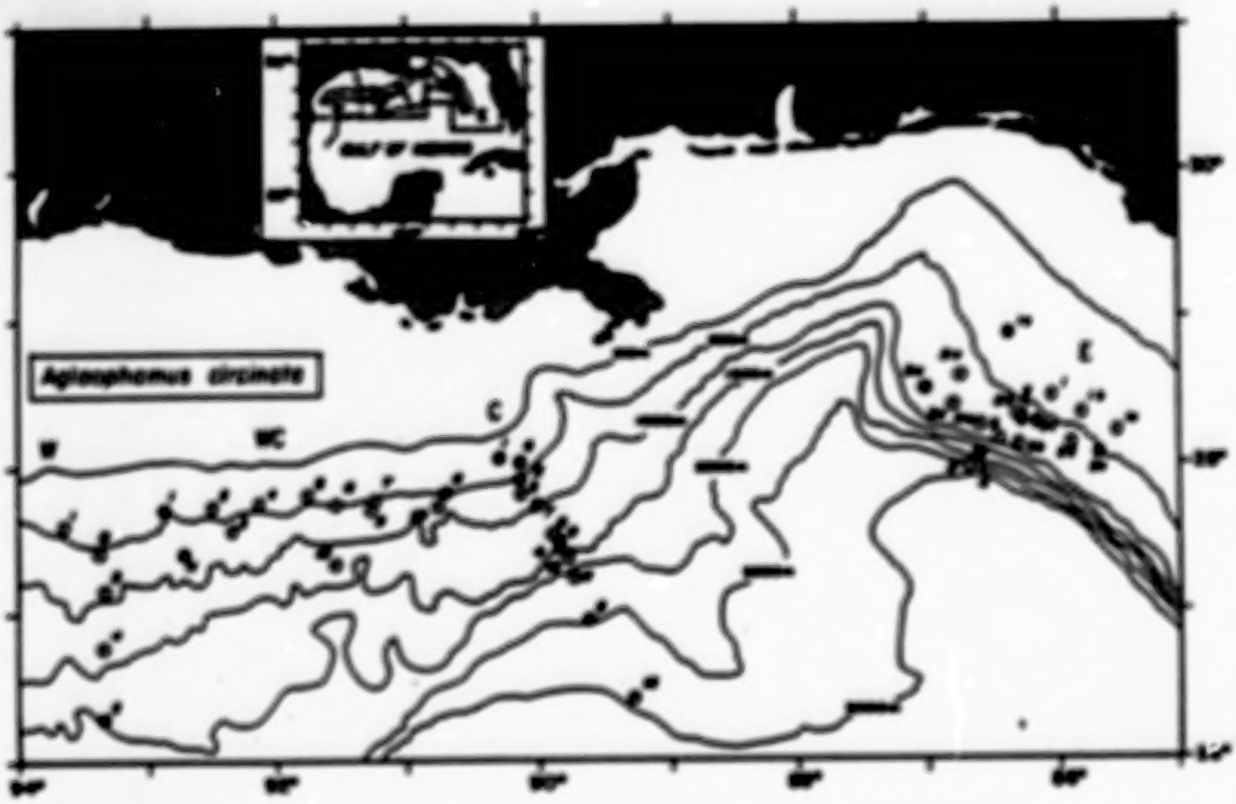
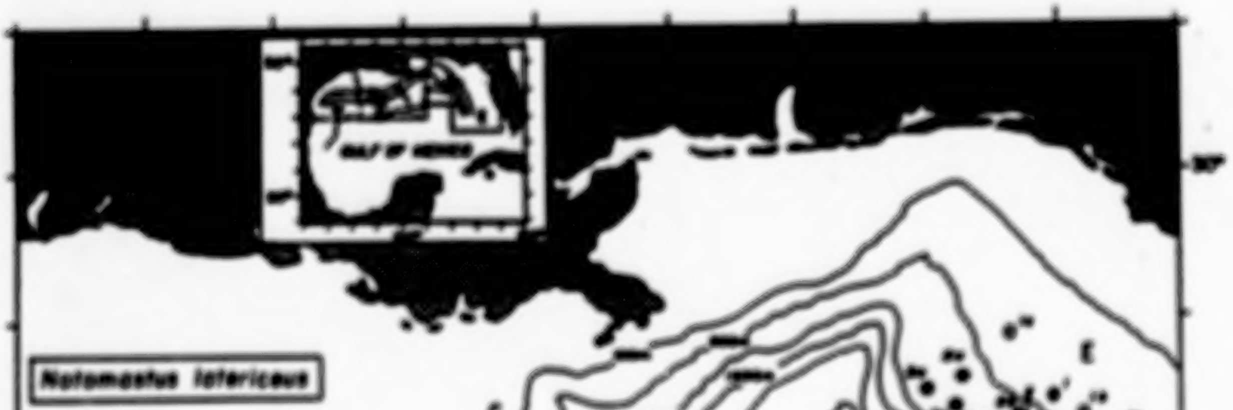

Aglaophamus circinata
GULF OF MEXICO
W
WC
C
E


Notomastus latericeus
GULF OF MEXICO
W
WC
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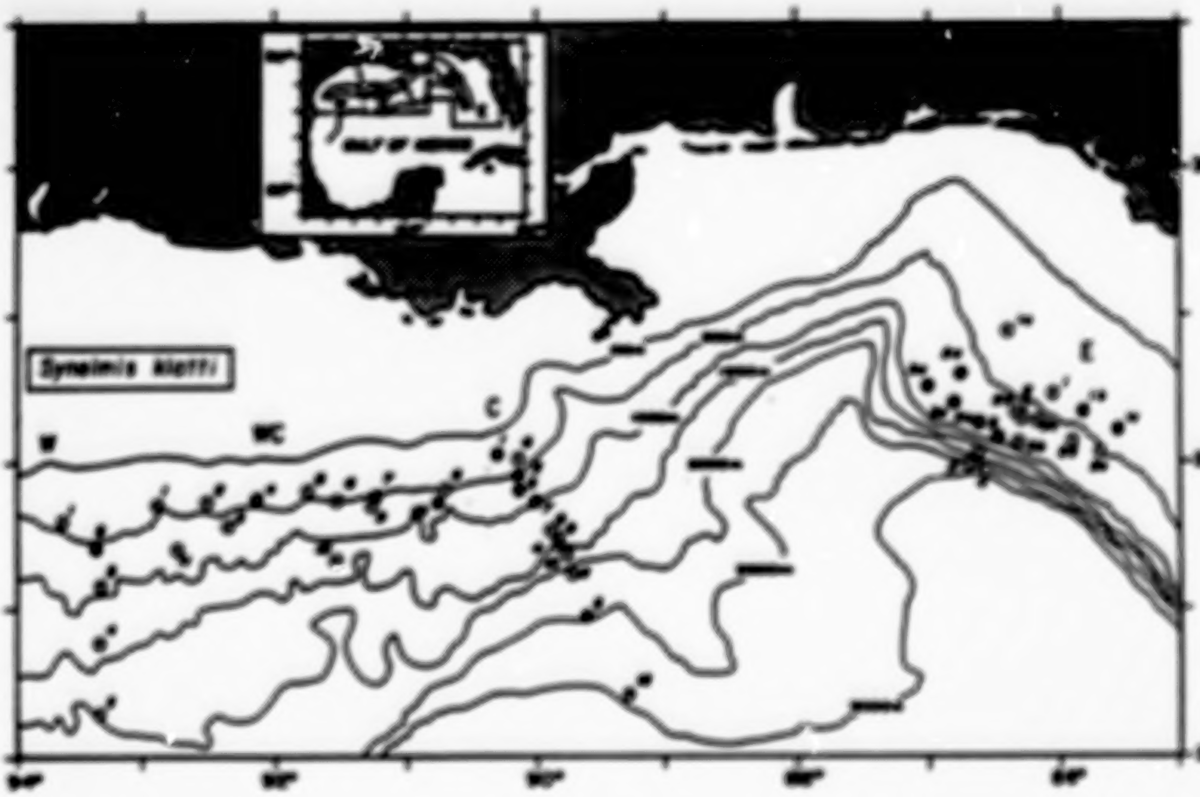
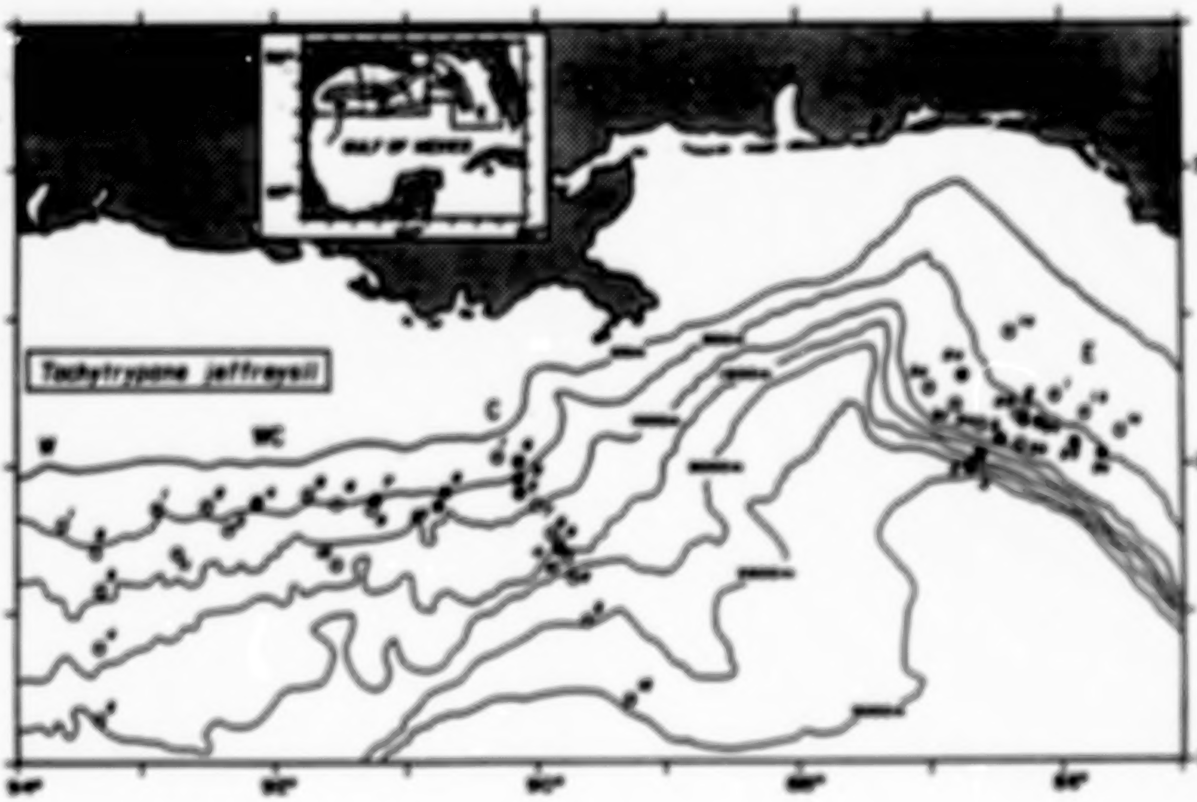
E


Synelmis klatti
W
WC
C
E


Tachytrypane jeffreysii
W
WC
C
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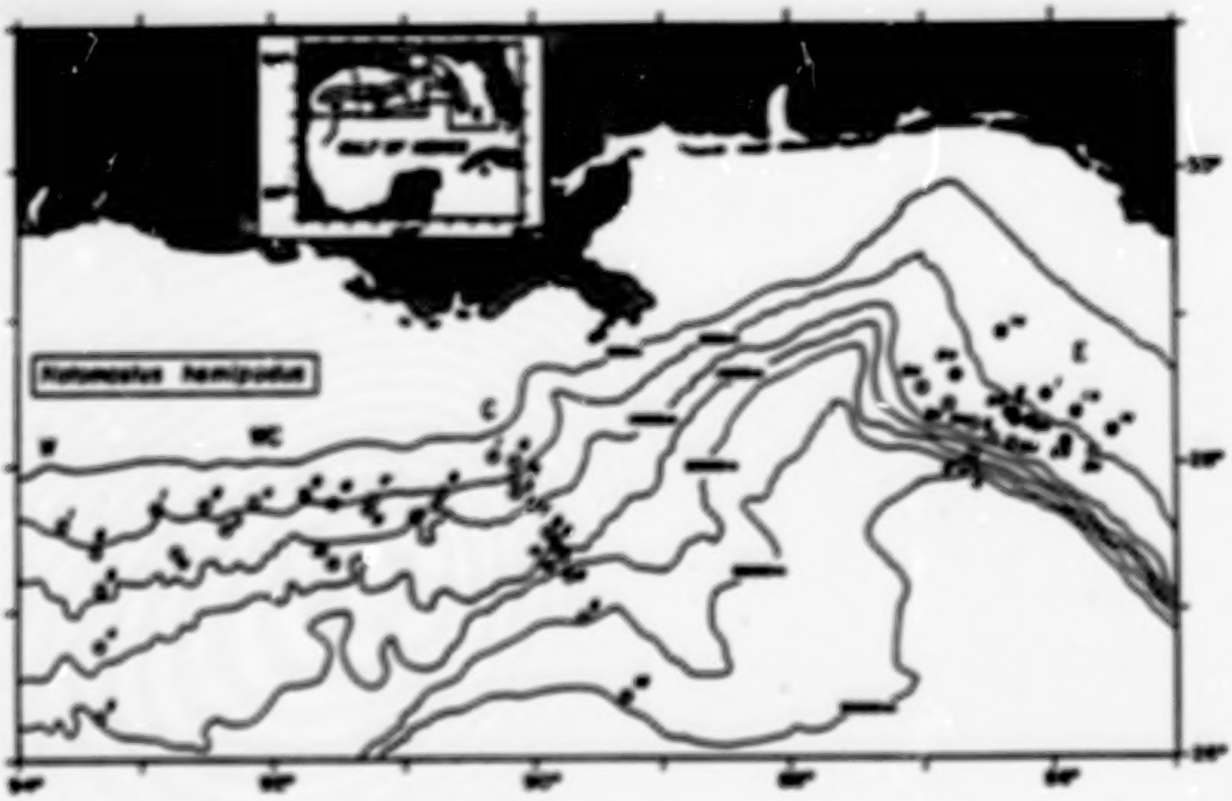
Notomastus hemipodus
GULF OF MEXICO
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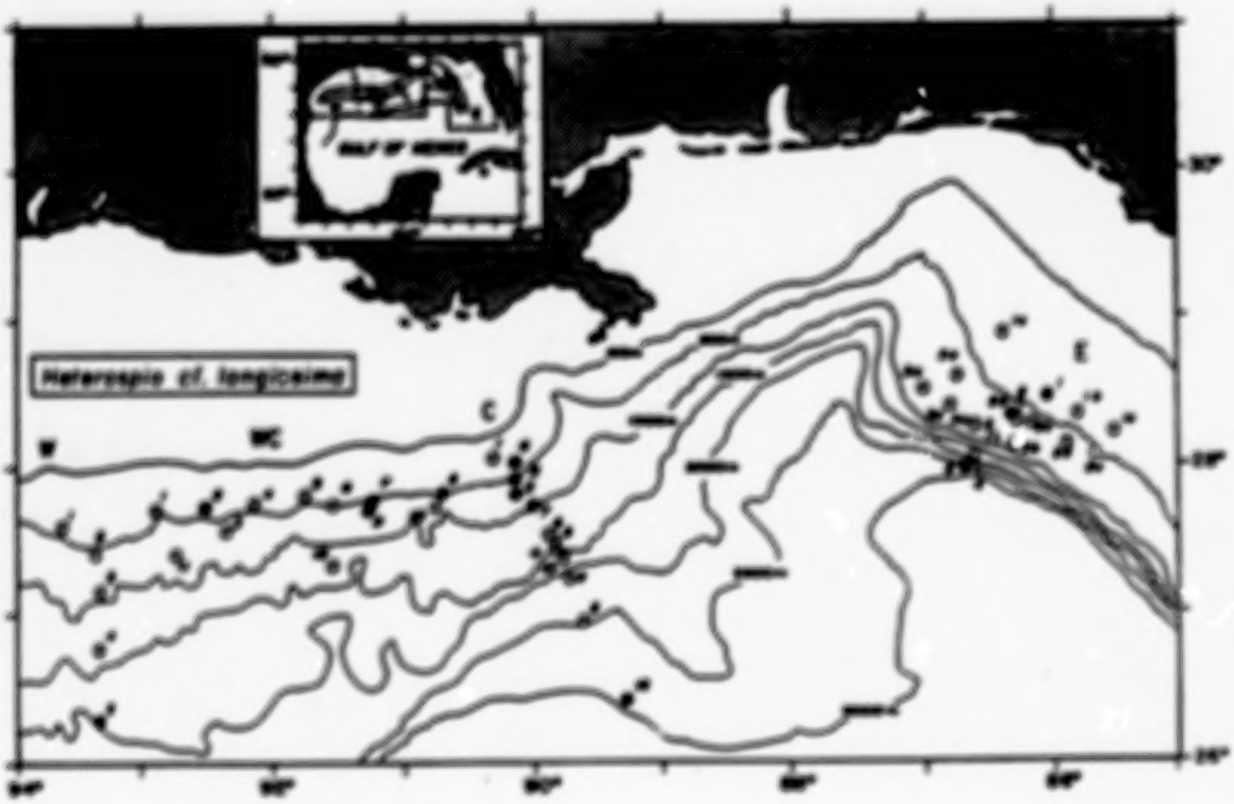
Heterospio cf. longissima
GULF OF MEXICO
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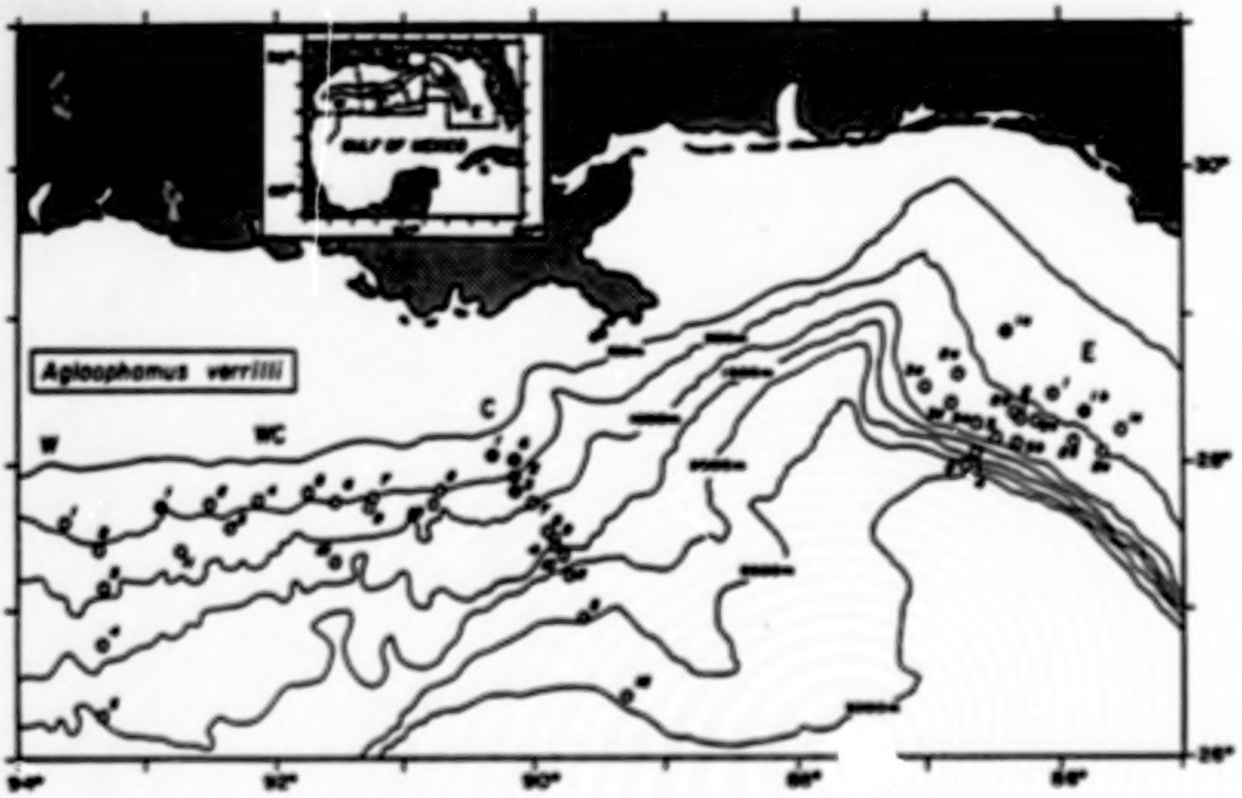
Aglaophamus verrillii
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GULF OF MEXICO
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ATTACHMENT A2.9: Summary of Invertebrate Species Found in the Trawl

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Attachment A2.9. Summary of invertebrate species found in the trawl. (Depth range is in meters.)

Taxa	Abundance	Number of Stations	Depth Range
ACTINIARIA			
ZOANTHIDEA	380	11	342 - 1135
ACTINAUGE LONGICORNIS	204	19	329 - 2504
HORMATHIIDAE	21	3	342 - 1735
AMPHIANTHUS OR ?STEPHENAUGE SP.	17	1	2400
ISANTHIDAE	16	1	627
HORMATHIIDAE "SHELL FORMER"	13	5	423 - 751
ANTHOLOBA PERDIX	6	5	329 - 474
ACTINOSCYPHIA SAGINATA	5	2	751 - 2074
ACTINIIDAE	5	1	802
HALCURIAS PILATUS	2	1	342
ACTINOSTOLIDAE	1	1	338
ALCYONARIA			
CHRYSOGORGIA AGASSIZII	1283	15	351 - 1170
ACANELLA EBURNEA	177	11	615 - 2057
ANTHOPTILUM GRANDIFLORUM	77	2	2400 - 2504
ACANELLA SP.	41	7	479 - 2074
ACANELLA ARBUSCULA	22	3	812 - 2401
PARAMURICEA SP.	13	1	663
SWIFTIA EXSERTA	8	1	464
ACANTHOGORGIA ASPERA	8	1	663
CANDIDELLA SP.	4	1	1438
MURICEIDES HIRTA	3	1	464
PARAMURICEA PLACOMUS	3	1	360
CALLOGORGIA VERTICILLATA?	2	1	464
TELESTO N.SP.	1	1	663
AMPHIPODA			
EPIMERA SP.	16	5	834 - 1206
ANONYX SP.	11	2	627 - 850
EPIMERIA SP.1	6	2	964 - 1170
VALETTIOPSIS SP.1	4	4	521 - 1438
TRISCHIZOSTOMA LONGIROSTRE?	3	2	1170 - 2857
EPIMERIA N.SP.2	2	1	1064
OEDICEROIDES ABYSSORUM?	2	2	1170 - 1440
EURONYX SP.	1	1	627
ASCIDIACEA			
BATHYSTYELOIDES ENDERBYANUS	1	1	2400
ASTEROIDEA			
PERSEPHONASTER ECHINULATUS	186	15	474 - 774
PECTINASTER GRACILIS	158	13	603 - 850
PLUTONASTER INTERMEDIUS	146	9	850 - 2504

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
ZOROASTER FULGENS	109	12	612 - 2400
NYMPHASTER ARENATUS	102	25	351 - 1735
GONIOPECTEN [illegible]	58	6	751 - 850
PLINTHASTER DENTATUS	49	19	474 - 2504
DYTASTER INSIGNIS	36	1	2504
PSEUDARCHASTER GRACILIS	33	10	612 - 2400
ASTROPECTEN AMERICANUS	24	4	329 - 368
ODONTASTER SETOSUS	17	10	345 - 842
BENTHOPECTEN SIMPLEX	10	3	2074 - 2504
PTERASTER PERSONATUS	7	1	2074
BRISINGIDAE	7	4	663 - 2504
HYMENASTER MODESTUS	5	4	551 - 1203
CAYMANOSTELLA SP.	5	2	627 - 1203
ODONTASTER HISPIDUS	5	3	342 - 663
BENTHOPECTINIDAE	4	1	625
HENRICIA ANTILLARUM	4	2	1064 - 1170
DIPSACASTER SP.	4	3	805 - 2313
ASTROPECTINIDAE	3	2	338 - 774
PSEUDARCHASTER SP.	3	1	2313
HYMENASTER SP.	3	2	654 - 1170
ANTHENOIDES PIERCEI	3	1	329
LITONOTASTER ROTUNDIGRANULUM	2	1	1203
PLUTONASTER AGASSIZI	2	1	774
PTERASTERIDAE	2	1	627
ASTROPECTEN SP.	2	2	625 - 663
MEDIASTER PEDICELLARIS	2	1	964
LITONOTASTER INTERMEDIUS	2	2	2074 - 2504
GONIASTERIDAE	2	2	612 - 850
PSILASTER CASSIOPE	2	2	746 - 850
SCLERASTERIAS CONTORTA	1	1	464
CIRCEASTER AMERICANUS	1	1	615
DORASTER CONSTELLATUS	1	1	351
TOSIA PARVA	1	1	1313
NOVODINIA ANTILLENSIS	1	1	964
CHEIRASTER MIRABILIS	1	1	802
HYMENASTERIDAE	1	1	621
CERAMASTER GRENADENSIS	1	1	1438
ASTROPECTEN COMPTUS	1	1	329
BIVALVIA			
PROPEAMUSSIUM SP.A	304	11	774 - 1510
PROPEAMUSSIUM SP.C	228	18	612 - 2400
PROPEAMUSSIUM DALLI	161	4	338 - 1438
ANODONTIA PHILIPPIANA?	117	1	342
LITHOPHAGA ANTILLARUM?	57	2	627 - 1203

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
AMYGDALUM POLITUM?	36	17	345 - 1135
PROPEAMUSSIUM SP.D	32	3	521 - 632
POROMYA SP.A	24	8	618 - 786
LIMOPSIS AURITA?	18	3	1204 - 1410
TELLINA SP.B	18	6	751 - 2400
LUCINOMA FILOSA	13	3	342 - 850
MACRODON (BENTHARCA) ASPERULA	11	1	663
LYONSIELLA SP.A	9	4	368 - 2504
PROPEAMUSSIUM SP.B	8	1	774
BANKIA SP.	8	2	850 - 1203
LYONSIA SP.A	8	4	551 - 663
CUSPIDARIA SP.A	8	5	612 - 629
MALLETIA SP.A	8	1	2400
TELLINA SP.A	7	4	329 - 632
MYONERA PAUCISTRIATA	4	4	464 - 1135
PARVAMUSSIUM CANCELLATUM	3	1	751
XYLOPHAGA ABYSSORUM	3	1	625
POROMYA ROSTRATA	3	2	345 - 350
CUSPIDARIA SP.	3	2	2313 - 2400
CALYPTOGENA PONDEROSA	3	1	850
PROPEAMUSSIUM HOLMESII	2	1	663
CUSPIDARIA OBESA	2	2	345 - 1203
CARDIOMYA SP.	2	2	663 - 1064
EULAMELLIBRANCH SP.B	2	1	2400
CUSPIDARIA ROSTRATA?	2	2	329 - 350
NUCULANIDAE	1	1	812
LUCINA SP.	1	1	612
LIMA SP.	1	1	612
BATHYARCA SP.A	1	1	612
PARVAMUSSIUM POURTALESIANUM	1	1	350
NUCULANA PLATESSA	1	1	345
POROMYA SP.	1	1	621
[illegible] SP.	1	1	603
NUCULA CALLICREDEMNA	1	1	342
VESICOMYA CORDATA	1	1	850
LIMOPSIS SP.	1	1	850
BRACHIOPODA			
[illegible]	45	1	964
PLATIDIA ANOMIOIDES	4	2	664 - 751
CEPHALOPODA			
ROSSIA BULLISI	12	5	342 - 621
ALLOPOSUS MOLLIS	11	7	354 - 663
PHOLIDOTEUTHIS ADAMI	7	6	627 - 1170

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
BENTHOCTOPUS JANUARII	5	4	464 - 551
ROSSIA SP.	4	2	479 - 812
STOLOTEUTHIS SP.	3	2	551 - 627
PTEROCTOPUS TETRACIRRHUS	2	2	350 - 603
SEMIROSSIA EQUALIS	3	1	329
OCTOPODIDAE	2	1	627
OPISTHOTEUTHIS AGASSIZI	2	1	802
OCTOPUS BURRYI	2	2	329 - 338
OCTOPUS SP.	1	1	464
LOLIGINIDAE	1	1	350
OCTOPUS JOUBINI	1	1	2313
OCTOPUS DEFILIPPI	1	1	2313
CIRRIPEDIA			
TRILASMIS KAEMPFERI INAEQUILATERAL	561	14	329 - 1735
CYPRIS LARVAE	453	2	802 - 1735
VERRUCA FLORIDANA	194	6	354 - 774
ARCOSCALPELLUM PORTORICANUM BRO	71	6	345 - 629
OCTOLASMIS [illegible]	46	1	384
LITOSCALPELLUM REGINA	26	4	423 - 521
AMIGDOSCALPELLUM SEMISCULPTUM	26	6	615 - 1203
VERRUCA NEXA	25	1	329
EUSCALPELLUM STRATUM	15	4	342 - 627
VERUM IDIOPLAX	10	6	774 - 1510
LITOSCALPELLUM GIGANTEUM	7	2	521 - 751
TELOSCALPELLUM ANTILLARUM	7	3	351 - 621
MEGALASMA CARINATUM	4	1	2401
BALANUS IMPROVISUS	3	2	464 - 663
AMIGDOSCALPELLUM AURIVILLII AURIVIL	3	2	612 - 2074
CATHERINUM ALBATROSSIANUM?	3	2	2074 - 2400
VERRUCA EUCLYPTA	1	1	751
CRINOIDEA			
DEMOCRINUS BREVIS	226	19	351 - 2400
ATELECRINUS BALANOIDES	67	15	479 1708
CARYOMETRA LISA	11	2	612 - 774
CARYOMETRA ALOPE	7	3	521 - 663
CARYOMETRA SP.	1	1	746
COMATULIDA	1	1	615
DECAPODA			
NEMATOCARCINUS ROTUNDUS	3393	35	521 - 1510
PENAEOPSIS SERRATA	2896	11	329 - 464
BATHYPLAX TYPHLA	2297	25	366 - 1438
PLESIONIKA HOLTHUISI	1664	24	366 - 871

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
MUNIDA VALIDA	1634	28	464 - 1170
BENTHOCHASCON SCHMITTI	1390	18	329 - 840
STEREOMASTIS SCULPTA	695	34	603 - 2857
UROPTYCHUS NITIDUS	342	20	251 - 1510
GLYPHOCRANGON NOBILIS	336	13	774 - 2313
GLYPHOCRANGON ACULEATA	314	18	751 - 2857
NEPHROPSIS ACULEATA	243	14	329 - 632
MUNIDA LONGIPES	233	13	329 - 1135
PONTOPHILUS GRACILIS	207	30	342 - 2857
PARAPANDALUS WILLISI	206	11	329 - 464
HYMENOPENAEUS ROBUSTUS	184	17	342 - 654
BENTHESICYMUS BARTLETTI	166	20	746 - 2074
GLYPHOCRANGON ALISPINA	161	16	423 - 871
GERYON QUINQUEDENS	125	29	366 - 2074
MUNIDOPSIS ROBUSTA	108	14	342 - 746
PARAPAGURUS PICTUS	102	13	342 - 2313
LYREIDUS BAIRDII	102	7	329 - 473
MUNIDOPSIS ERINACEUS	97	13	474 - 774
HETEROCARPUS ORYX	87	7	812 - 1438
PARAPAGURUS PILOSIMANUS	87	12	603 - 1510
ROCHINIA CRASSA	82	20	338 - 1170
PLESIONIKA TENUIPES	81	8	345 - 423
PARAPENAEUS LONGIROSTRIS	79	4	329 - 366
PYROMAIA ARACHNA	74	11	329 - 423
POLYCHELES TYPHLOPS	69	12	338 - 663
HYMENOPENAEUS DEBILIS	69	10	474 - 1170
MUNIDOPSIS LONGIMANUS	46	18	350 - 1208
PLESIONIKA ACANTHONOTUS	43	11	464 - 629
MUNIDOPSIS SIGSBEI	41	10	479 - 1510
NEPHROPSIS ROSEA	34	11	603 - 1170
GLYPHOCRANGON LONGLEYI	29	12	464 - 654
TRICHOPELTARION NOBILE	28	5	603 - 786
PARAPAGURUS ALAMINOS	27	7	850 - 2504
ACANTHACARIS CAECA	23	9	521 - 751
PAGURUS ROTUNDIMANUS	23	8	342 - 751
SYSTELLASPIS PELLUCIDA	22	3	368 - 842
ACANTHEPHYRA EXIMIA	21	2	1170 - 1208
ETHUSA MICROPHTHALMA	21	6	329 - 706
PALICUS GRACILIS	19	10	329 - 615
MUNIDOPSIS IMPOLITA	15	9	345 - 663
MUNIDOPSIS BAHAMENSIS	14	2	423 - 663
CATAPAGUROIDES MICROPS	14	7	751 - 1440
PRIONOCRANGON PECTINATA	14	10	521 - 1203
MUNIDOPSIS SPINOSA	13	4	751 - 829
CYMONOMUS N.SP.A	13	8	612 - 850

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
MUNIDOPSIS ABBREVIATA	12	6	774 - 1170
THALASSOPLAX ANGUSTA	12	5	338 - 464
ROCHINIA UMBONATA	12	8	612 - 871
ACANTHEPHYRA ARMATA	12	6	751 - 1170
PHYLLADIORHYNCHUS N. SP.	11	1	663
MUNIDA MICROPHTHALMA	11	5	964 - 2401
MUNIDOPSIS SIMPLEX	10	4	850 - 1510
ACANTHOCARPUS ALEXANDRI	10	4	329 - 368
[illegible]	9	2	2074 - [illegible]
HETEROCARPUS ENSIFER	9	5	342 - 368
MUNIDOPSIS ALAMINOS	8	5	479 - 663
RICHARDINA SPINICINCTA	8	4	551 - 774
NEPHROPSIS AGASSIZI	8	7	812 - [illegible]
MUNIDOPSIS POLITA	8	7	342 - 1170
MUNIDA CONSTRICTA	7	3	612 - 627
BENTHESICYMUS CEREUS/IRIDESCENS	7	1	2504
BATHYPALAEMONELLA SERRATIPALMA	7	4	850 - 1203
GASTROPTYCHUS SPINIFER	7	4	345 - 2401
PLESIOPENAEUS EDWARDSIANUS	7	6	621 - 1135
PSALIDOPUS BARBOURI	7	6	618 - 786
NEMATOCARCINUS ENSIFER	6	3	2074 - 2504
BATHYNECTES SUPERBA	6	4	338 - 368
HOMOLODROMIA PARADOXA	5	3	627 - 751
ROCHINIA HYSTRIX	5	3	351 - 625
POLYCHELES CRUCIFER	5	3	751 - 1135
LITHODES AGASSIZII	5	4	774 - 1438
MUNIDA FORCEPS	5	3	329 - 368
MUNIDOPSIS N. SP.	4	2	663 - 751
PARADALIDAE	4	2	479 - 521
FUNCHALIA TAANINGI	4	1	350
GERYON FENNERI	4	2	345 - 350
AXIOPSIS SP.A	4	4	366 - 629
HYMENOPENAEUS APHOTICUS	4	4	1135 - 2504
HETEROCARPUS LAEVIS	3	1	663
ARISTEOMORPHA FOLIACEA	3	2	464 - 521
THAUMASTOCHELES ZALEUCUS	3	2	842 - 871
CYMONOMUS SP.D	3	3	612 - 627
PARAPAGURUS SP.	3	3	464 - 802
PORCELLANA SIGSBEIANA	3	2	329 - 338
EUMUNIDA PICTA	2	1	663
CALLINECTES SIMILIS	2	1	368
MUNIDOPSIS SPINOCULATA	2	1	871
DORHYNCHUS THOMSONI	2	2	627 - 663
MUNIDOPSIS RAMAHTAYLORAE	2	2	612 - 627
ETHUSA SP.	2	2	350 - 368

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
PROCESSA PROFUNDA	2	2	354 - 368
METACRANGON JACQUETI AGASSIZII	2	1	964
MUNIDA SP.	2	2	366 - 621
TRIZOCARCINUS TACITUS	2	2	345 - 366
PONTOCARIS CARIBBAEUS	2	2	329 - 346
HOMOLIDAE	1	1	1203
HOMOLOGENUS ROSTRATUS	1	1	1203
BYTHOCARIS SP.A	1	1	1135
ROBERTSELLA MYSTICA	1	1	479
MUNIDOPSIS ?ARIES	1	1	663
MUNIDOPSIS SERRATIFRONS	1	1	663
TOMOPAGURUS COKERI	1	1	368
MUNIDA EVERMANI	1	1	368
PLESIONIKA EDWARDSII	1	1	350
TRIZOCARCINUS SP.	1	1	350
HIPPOLYTIDAE	1	1	350
MUNIDA MILES	1	1	345
GONEPLACIDAE	1	1	345
POLYCHELES VALIDUS	1	1	2074
HEMIPENAEUS CARPENTERI	1	1	2074
PARAPAGURUS NUDUS	1	1	2504
ACANTHEPHYRA MICROPHTHALMA	1	1	2504
PERICLIMENES PANDIONIS	1	1	632
SPONGICOLOIDES N.SP.	1	1	1170
BATHYPALAEMONELLA TEXANA	1	1	1170
PLESIONIKA LONGIPES	1	1	366
STENOCIONOPS SPINIMANA	1	1	342
SCYLLARUS CHACEI	1	1	342
MUNIDA IRRASA	1	1	342
PARAPAGURUS BICRISTATUS	1	1	850
PAGURISTES SP.	1	1	329
SOLENOCERA NECOPINA	1	1	329
COLLODES LEPTOCHELES	1	1	329
CHACELLUS FILIFORMIS	1	1	329
ECHINOIDEA			
PLESIODIADEMA ANTILLARUM	70	6	751 - 1440
BRISSOPSIS ALTA	19	3	329 - 615
HOMOLAMPAS FRAGILIS	17	6	615 - 629
BRISSOPSIS SP.	13	1	329
ACESTE BELLIDIFERA	7	3	615 - 629
ECHINOCYAMUS GRANDIPORUS	6	4	612 - 629
PHORMOSOMA PLACENTA	6	3	1438 - 1510
PODOCIDARIS SCULPTA	4	1	663
BRISSOPSIS ATLANTICA	2	1	329

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
CIDARIS RUGOSA	1	1	663
ECHINUS TYLODES	1	1	1735
ECHINOCYAMUS MACROSTOMUS	1	1	1064
ASPIDODIADEMA JACOBYI	1	1	1064
GASTROPODA			
OOCORYS SULCATA	45	3	2074 - 2504
BUCCINUM CANETAE	29	8	612 - 764
LEUCOSYRINX TENOCERAS	26	9	774 - 1510
SOLARIELLA LAMELLOSA	25	6	612 - 629
HYALORISIA GALEA	21	4	338 - 774
SCAPHANDER WATSONI	21	2	[illegible]
XENOPHORA LONGLEYI	17	9	338 - 627
ADMETE SP.	16	1	627
LEUCOSYRINX VERRILLI	7	3	774 - 1203
CORINNAETURRIS INCLIS	7	3	612 - 625
PLEUROBRANCHAEA SP.	6	2	464 - 479
CORINNAETURRIS LEUCOMATA	6	4	612 - 1203
TROCHIDAE N. SP.	6	3	612 - 850
GAZA SUPERBA	5	4	551 - 774
ANCISTROSYRINX SP.	[illegible]	4	610 - 671
TROCHIDAE	5	2	615 - 627
CERITHIUM N. SP.	5	1	345
CANTRAINEA N.SP.	4	1	964
SCAPHANDER CLAVUS	4	4	603 - 1170
CORALLIOPHILA RICHARDI	3	1	663
GYMNOBELA SP.	3	2	964 - 1510
PHILINE ALBA	3	1	329
COCCULINA SP.	2	2	521 - 1203
GEMMULA PERISCELIDA	2	1	368
SOLARIELLA PERSTRIATA	2	2	842 - 1203
MITRA BAIRDII	2	1	625
CORINNAETURRIS SP.	2	2	871 - 1170
SCAPHELLA DUBIA	2	2	329 - 474
BENTHOBIA TRYONI	1	1	751
SCAPHELLA GOULDIANA	1	1	464
FISSURELLA SP.	1	1	663
SOLARIELLA TIARA	1	1	812
PLEUROBRANCHIDAE	1	1	627
PECTINODONTA ARCUATA	1	1	627
SPIROTROPIS SP.	1	1	618
DRILLIOLA SP.	1	1	612
PLEUROTOMELLA SP.	1	1	625
INODRILLIA SP. B	1	1	345
INODRILLIA SP. A	1	1	345

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
OOCORYS BARTSCHI	1	1	802
ARMINA SP.	1	1	346
TROPHON ACULEATUS	1	1	1170
GAZA FISCHERI	1	1	829
CYLICHNIUM SPATHA	1	1	2400
SCAPHANDER BATHYMOPHILUS	1	1	850
HOLOTHUROIDEA			
MESOTHURIA LACTEA	184	17	474 - 1170
BENTHODYTES TYPICA	101	3	2074 - 2504
ENYPNIASTES SP.	74	4	621 - 2504
MOLPADIA BARBOURI	44	15	679 - 2400
MOLPADIA MUSCULUS	38	9	479 - 2400
SPHAEROTHURIA TALISMANI	26	7	350 - 625
PSYCHROPOTES DEPRESSA	23	2	2074 - 2504
BATHYPLOTES NATANS?	12	3	366 - 2504
MOLPADIA BLAKEI	10	6	551 - 2074
BENTHODYTES LINGUA	8	3	2074 - 2504
AMPHIGYMNAS BAHAMENSIS	7	4	464 - 663
PSEUDOSTICHOPUS SP	7	2	1064 - 2074
ECHINOCUCUMIS HISPIDA	7	5	618 - 1440
PSEUDOSTICHOPUS SP. A	6	2	1438 - 2316
PROTANKYRA SP.	6	2	2400 - 2504
BENTHODYTES SANGUINOLENTA	4	1	1208
PSEUDOSTICHOPUS SP. B	3	1	2316
MOLPADIA AGASSIZI?	1	1	551
MOLPADIA SP.	1	1	850
DEIMA VALIDUM	1	1	1510
MOLPADIA CUBANA	1	1	338
HYDROZOA			
LYTOCARPIA [illegible]	55	8	345 - 871
EUDENDRIUM EXIMIUM	3	2	618 - 871
CLADOCARPUS TENUIS	3	2	618 - 629
CLADOCARPUS [illegible]	2	1	629
ACRYPTOLARIA CONFERTA	1	1	464
ISOPODA			
AEGA SP.285	1001	7	366 - 2857
BATHYNOMUS GIGANTEUS	111	11	479 - 1170
AEGA SP.297	6	4	625 - 774
ROCINELA SP.296	3	5	354 - 625
CIROLANA SP.282	4	2	479 - 677
AEGA SP.299	1	1	663
MEINERTIA SP. 287	1	1	621

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
MISC. ANTHOZOA			
ANTIPATHARIA SP.B	35	1	663
ANTIPATHARIA SP.A	8	1	663
ANTIPATHARIA SP.C	1	1	663
CERIANTHIDAE	1	1	627
NEMERTEA			
NEMERTEA SP.L	1	1	1208
NEMERTEA	1	1	618
OPHIUROIDEA			
OPHIERNUS ADSPERSUS	1087	19	423 - 850
AMPHILEPIS PLATYTATA	959	3	612 - 2504
OPHIOCAMAX FASCICULATA	857	3	663 - 1422
BATHYPECTINURA HEROS	279	18	366 - 2504
OPHIURA SP.A	209	11	663 - 1440
OPHIOCHITON GRANDIS	173	17	423 - 1170
OPHIOLIPUS AGASSIZII	153	16	329 - 850
AMPHIOPHIURA SCULPTILIS	123	11	618 - 1440
OPHIOPRIUM PERMIXTUM	113	15	464 - 1170
OPHIOSPHALMA ARMIGERUM	92	10	612 - 2504
[illegible]	43	9	612 - 812
OPHIACANTHA SP.B	28	7	612 - 629
[illegible]	25	10	464 - 850
OPHIACANTHA SP.A	24	2	621 - 850
OPHIACANTHA VALENCIENNESI	21	1	663
JUVENILE OPHIURINAE	19	9	612 - 1170
OPHIOMUSIUM ACUFERUM	17	3	345 - 354
OPHIURA FALCIFERA	17	7	612 - 812
HISTAMPICA DUPLICATA	17	6	627 - 1510
OPHIOCHITONIDAE	12	4	368 - 627
AMPHIURA SEMIERMIS	7	3	612 - 834
OPHIACANTHA ECHINULATA	7	6	612 - 1208
HOMALOPHIURA INORNATA	7	3	850 - 2504
AMPHIOPLUS DALEUS	6	1	2400
OPHIOMUSIUM TESTUDO	5	5	850 - 2504
AMPHIURA SP.A (CF. FLEXUOSA)	4	4	627 - 774
AMPHIOPLUS INCISUS	4	4	663 - 1064
AMPHIOPLUS SP.B	2	2	479 - 663
OPHIOMUSIUM EBURNEUM	2	1	346
AMPHIURA SP.	2	1	621
OPHIERNUS VALLINCOLA	2	2	2074 - 2400
OPHIURA ACERVATA	2	1	329
ANTHOPHIURA INGOLFI	1	1	464

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
AMPHIOPLUS CUNEATUS?	1	1	663
OPHIACTIS ABYSSICOLA?	1	1	663
OPHIACANTHA SP. C	1	1	663
OPHIOMYXA TUMIDA	1	1	663
OPHIOCREAS LUMBRICUS?	1	1	368
AMPHIOPLUS SP. A	1	1	850
OPHIAMBIX SP.	1	1	627
AMPHITARSUS MIRABILIS	1	1	615
[illegible]	1	1	621
ASTEROSCHEMA TENUE?	1	1	342
OPHIOMUSIUM SP.	1	1	2400
OPHIOCREAS SPINULOSUS	1	1	850
POGONOPHORA/VESTIMENTIFERA			
GALATHEALINUM N. SP.	122	1	464
LAMELLIBRACHIA SP.	5	1	464
POLYCHAETA			
HYALINOECIA TUBICOLA	219	17	612 - 1510
EUNICE NORVEGICA	65	13	350 - 1064
ISOLDA PULCHELLA	27	8	612 - 663
EUNICE HUBRECHTI	23	3	368 - 663
EUNICE SP. A	14	7	474 - 1510
SARSONUPHIS HARTMANAE	13	2	834 - 2074
EUNICE CONGLOMERANS	11	2	342 - 464
EHLERSILEANIRA INCISA	10	7	479 - 751
APHRODITA SP. A	9	4	612 - 627
MELINNA CRISTATA	8	2	612 - 621
KEFERSTENIA CIRRATA	7	1	663
MYRIOCHELE HEERI?	7	5	621 - 2400
SCIONELLA SP. A	7	1	2400
NEREIS (NEANTHES) SP. A	6	2	663 - 1203
RHAMPHOBRACHIUM SP. A	6	3	627 - 850
MALDANIDAE	6	3	850 - 2400
LUMBRINERIS COCCINEA	5	3	368 - 464
TEREBELLA EHRENBERGI?	5	3	342 - 354
AMELINNA ABYSSALIS	4	1	621
LAETMONICE SP.	3	1	368
SYLLIS (TYPOSYLLIS) ALTERNATA?	3	2	368 - 464
MYRIOGLOBULA SP. A	3	1	618
SPIOCHAETOPTERUS COSTARUM	3	2	615 - 625
HAPLOSYLLIS SPONGICOLA	3	2	342 - 663
AMPHICTEIS SP. A	3	1	2400
TEREBELLIDAE	3	3	351 - 1440
POLYNOIDAE	2	2	1135 - 1203

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
EUNI[illegible]	2	1	464
AMPHARETIDAE GENUS F	2	2	629 - 834
CHAETOZONE "SP.A"	2	1	627
PARADIOPATRA [illegible]	2	2	618 - 627
ARCTONOE SP.A	2	2	479 - 618
AMPHARETIDAE	2	2	464 - 612
MARPHYSIA SP.A	2	1	612
LEANIRA HYSTRICUS	2	2	612 - 871
GYPTIS SP.B	2	2	1064 - 17[illegible]
TEREBELLIDES STROEMI	2	2	474 - 627
CHLOEIA VIRIDIS	2	2	632 - 663
LAETMONICE BENTHALIANA?	2	2	346 - 350
HYALINOECIA JUVENALIS	2	2	621 - 774
HARMOTHOE SP.	2	2	342 - 464
SARSONUPHIS PAUCIBRANCHIS	2	1	2400
ASYCHIS GOTOI?	2	2	621 - 850
EURYTHOE SP.A	1	1	1208
NEPHTYS SP.A	1	1	1208
MARPHYSIA SP.B	1	1	1135
AGLAOPHAMUS CIRCINATA	1	1	479
LUMBRINERIS VERRILLI	1	1	464
CERATOCEPHALE OCULATA	1	1	464
SYLLIS (TYPOSYLLIS) "SP.C"	1	1	464
NEOLEPRIA "SP.A"	1	1	464
DASYBRANCHUS LUNULATUS	1	1	663
METAVERMILIA SP.	1	1	663
LYSIDICE NINETTA	1	1	663
PRIONOSPIO (MINUSPIO) "SP.A"	1	1	521
TEREBELLA SP.A	1	1	368
PISTA CRISTATA	1	1	834
PULLIELLA ARMATA	1	1	627
NEREIS (NEANTHES) SUCCINEA	1	1	612
NOTHRIA TEXTOR	1	1	612
LUMBRINERIDAE	1	1	351
PARONUPHIS SP.A 1	1	1	2074
SYNELMIS KLATTI	1	1	621
MALDANIDAE GENUS D	1	1	621
MALDANIDAE GENUS C	1	1	621
MALDANE GLEBIFEX	1	1	621
HOBSONIA SP.	1	1	621
AMPHARETIDAE GENUS G	1	1	621
RHODINE SP.B	1	1	621
STHENOLEPIS SP.A	1	1	828
APHRODITIDAE	1	1	654
SYLLIS (TYPOSYLLIS) PROLIFERA	1	1	342

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
OPHELINA SP.B	1	1	1440
PORIFERA			
POLYMASTIA SP.B	682	21	329 - 2857
THENEA SP.	652	8	612 - 1203
DESMACELLIDAE	596	1	1203
THENEA SP.A	309	4	621 - 2[illegible]
TETHYA SP.	282	9	612 - 1208
HYALONEMA SP.	84	19	479 - 1510
PACHASTRELLA SP.	24	1	663
REGADRELLA SP.	18	8	834 - 2313
TETHYA SP.B	15	2	621 - 1170
DESMACELLA SP.	8	2	368 - 663
HYALONEMATIDAE	6	3	812 - 1135
XESTOSPONGIA SP.	5	1	663
TETILLA SP.A	5	2	1413 - 2400
HEXACTINELLIDA	5	3	464 - 2504
PACHASTRELLA ABYSSI?	3	1	663
STYLOCORDYLA SP.	3	2	350 - 805
APHROCALLISTES SP.	2	2	663 - 751
CHONDROSIA SP.	2	1	805
THENEA SP.D	2	2	805 - 2313
LEUCOPSACASIDAE	2	1	342
CLATHRIDAE	1	1	751
CAULOPHACIDAE	1	1	464
HALICHONDRIIDAE	1	1	663
THENEA SP.B	1	1	621
PYCNOGONIDA			
PALLENOPSIS TYDEMANI CARIBBICA	1	1	[illegible]
PALLENOPSIS SCOPARIA	1	1	1064
SCAPHOPODA			
LAEVIDENTALIUM CALLIPEPLUM	5	2	345 - 368
DENTALIUM PERLONGUM	5	4	842 - 2400
DENTALIUM CIRCUMCINCTUM	2	2	834 - 842
PULSELLUM PRESSUM	1	1	774
SIPHONODENTALIIDAE	1	1	850
CADULUS SP.	1	1	842
SCLERACTINEA			
DELTOCYATHUS ITALICUS	80	21	551 - 1203
LOPHELIA PROLIFERA	48	1	663
STEPHANOCYATHUS DIADEMA	45	6	964 - 1510
CARYOPHYLLIA AMBROSIA CARIBBEANA	28	9	774 - 1203

Attachment A2.9 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
CARYOPHYLLIA BERTERIANA	8	2	464 - 751
FLABELLUM MOSELEYI	8	5	612 - 629
DENDROPHYLLIA ALTERNATA	4	1	368
STOMATOPODA			
SQUILLA EDENTATA	5	2	329 - 346

ATTACHMENT A2.10: Summary of Fish Species Found in Trawl

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Atachment A2.10. Summary of fish species found in the trawl.

Taxa	Abundance	Number of Stations	Depth Range
DIBRANCHUS ATLANTICUS	575	32	351 - 964
UROPHYCIS CIRRATUS	380	19	329 - 632
BEMBROPS GOBIOIDES	366	16	330 - 654
SYNAPHOBRANCHUS OREGONI	352	30	479 - 1510
CHLOROPHTHALMUS AGASSIZI	305	13	329 - 479
HYMENOCEPHALUS ITALICUS	257	10	342 - 551
NEZUMIA AEQUALIS	236	27	474 - 1438
COELORINCHUS COELORHINCUS	205	16	329 - 663
GADOMUS LONGIFILIS	191	11	751 - 1203
COELORINCHUS CARIBBAEUS	177	8	329 - 786
EPIGONUS PANDIONIS	175	17	329 - 828
POECILOPSETTA BEANI	155	13	329 - 905
CHAUNAX PICTUS	150	21	350 - 840
PERISTEDION GRAYAE	128	17	329 - 1170
LAEMONEMA BARBATULUM	116	14	423 - 663
MALACOCEPHALUS OCCIDENTALIS	111	19	329 - 663
MERLUCCIUS ALBIDUS	107	21	329 - 812
BATHYGADUS MACROPS	106	17	551 - 1170
BATHYGADUS MELANOBRANCHUS	97	16	603 - 1064
SETARCHES GUENTHERI	94	10	329 - 464
DIPLACANTHOPOMA SP.	94	17	464 - 840
DICROLENE SP.	93	20	746 - 1438
MONOMITOPUS SP.	87	16	479 - 1170
ILYOPHIS BRUNNEUS	84	13	746 - 1203
ETMOPTERUS SCHULTZI	62	13	464 - 774
STEPHANOBERYX MONAE	53	5	1064 - 1510
PARASUDIS TRUCULENTA	52	12	329 - 1170
CORYPHAENOIDES MEXICANUS	50	16	751 - 2074
NEZUMIA CYRANO	47	11	615 - 1170
PSEUDOPHICHTHYS LATERODORSALIS	41	11	603 - 871
STEINDACHNERIA ARGENTEA	38	7	329 - 423
HALOSAURUS GUENTHERI	34	10	751 - 1170
BROSMICULUS IMBERBIS	33	13	342 - 871
PONTINUS LONGISPINIS	30	4	329 - 351
CORYPHAENOIDES COLON	29	15	603 - 964
SYNAGROPS BELLA	26	10	[illegible]
HEMANTHIAS VIVANUS	25	9	329 - 368
BARATHRONUS BICOLOR	23	10	603 - 1735
GURGESIELLA SINUSMEXICANUS	21	13	342 - 1135
BATHYPTEROIS QUADRIFILIS	18	5	964 - 1735
UROPHYCIS FLORIDANUS	17	6	329 - 423
HOPLOSTETHUS OCCIDENTALIS	17	10	329 - 474
ALDROVANDIA GRACILIS	17	5	1064 - 1735
VENEFICA PROCERA	16	7	964 - 2857
ETMOPTERUS GRACILISPINIS	16	2	474 - 632

Attachment A2.10 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
BATHYGADUS FAVOSUS	16	4	1064 - 1203
NEZUMIA ATLANTICA	15	7	612 - 812
SYNAGROPS SPINOSA	14	5	342 - 354
POLYMIXIA LOWEI	13	5	329 - 423
GNATHAGNUS EGREGIUS	13	7	329 - 423
ALDROVANDIA AFFINIS	13	4	1064 - 1775
SYMPHURUS MARGINATUS	12	9	351 - 663
ETMOPTERUS VIRENS	12	3	464 - 479
NETTASTOMA MELANURA	11	8	618 - 850
FACCIOLELLA SP.	11	5	464 - 632
ARGENTINA STRIATA	11	6	329 - 368
ACROMYCTER PERTURBATOR	11	3	964 - 1170
YARELLA BLACKFORDI	10	6	603 - 850
NEOSCOPELUS MACROLEPIDOTUS	10	4	621 - 850
IPNOPS MURRAYI	10	2	1135 - 1413
SPHAGEMACRURUS GRENADAE	9	2	1064 - 1203
NEZUMIA SUILLA	8	4	828 - 1170
LOPHIUS GASTROPHYSUS	8	6	350 - 479
GADOMUS ARCUATUS	7	6	751 - 1170
EPTATRETUS SPRINGERI	7	6	474 - 774
CONOCARA SP.	7	2	1170 - 1203
BEMBROPS ANATIROSTRIS	7	5	345 - 1170
TRACHONURUS VILLOSUS	6	3	746 - 1170
PERISTEDION MINIATUM	6	4	329 - 423
MALACORAJA [illegible]	6	2	774 - 834
LYCENCHELYS BULLISI	6	5	625 - 1135
EPIGONUS OCCIDENTALIS	6	3	368 - 850
ARIOMMA SP.	6	2	751 - 1135
POLYACANTHONOTUS MERRETTI	5	3	842 - 1135
NEZUMIA SP.	5	5	464 - 1064
LOPHIODES MONODI	5	2	366 - 621
HYDROLAGUS SP.	5	4	551 - 834
DYSOMMINA RUGOSA	5	4	464 - 677
CRURIRAJA RUGOSA	5	4	521 - 786
BATHYPTEROIS GRALLATOR	5	2	2074 - 2504
APRISTURUS PROFUNDORUM	5	5	618 - 1135
SQUALOGADUS MODIFICATUS	4	2	1170 - 1203
NEZUMIA SCLERORHYNCHUS	4	1	474
MALACORAJA PURPURIVENTRALIS	4	3	802 - 1438
LUCIOBROTULA CORETHROMYCTER	4	3	625 - 774
GADOMUS DISPAR	4	2	663 - 871
DECHODONTES DAEDALEUS	4	3	479 - 834
CRURIRAJA CADENATI	4	1	345
CORYPHAENOIDES MACROCEPHALUS	4	3	1064 - 2504
CATAETYX SP.	4	4	964 - 1510

Attachment A2.10 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
BATHYPTEROIS VIRIDENSIS	4	4	627 - 1170
BATHYPTEROIS PHENAX	4	1	1170
BATHYPTEROIS BIGELOWI	4	2	625 - 834
APRISTRURUS PARVIPINNIS	4	4	751 - 871
TRACHYSCORPIA CHRISTULATA	3	2	612 - 615
RAJA GARMANI	3	3	329 - 360
POLYMETME CORYTHAEOLA	3	2	338 - 342
OPHICHTHUS SP.	3	2	464 - 774
NOTACANTHUS CHEMNITZI	3	3	629 - 751
HALOSAURUS OVENII	3	3	603 - 746
EPTATRETUS MINOR	3	1	464
DIPLOPHOS MADERENSIS	3	1	346
CONGRIDAE	3	3	551 - 632
BATHYGADUS SP.	3	2	663 - 774
ACANTHOBATUS FOLIROSTRIS	3	3	351 - 474
XYELACYBA MYERSI	2	1	1170
SYNAPHOBRANCHUS SP.	2	2	621 - 1440
SCYLIORHINUS RETIFER	2	1	354
NEZUMIA LONGEBARBATUS	2	1	1735
MELANONUS ZUGMAYERI	2	2	850 - 1203
MACROURIDAE	2	2	464 - 654
LUCIOBROTULA SP.	2	2	632 - 812
LEPTODERMA MACROPS	2	2	840 - 871
HOPLOSTETHUS MEDITERRANEUS	2	2	423 - 464
EPIGONUS MACROPS	2	1	829
EPIGONUS DENTICULATUS	2	2	464 - 521
COELORINCHUS SP.	2	2	871 - 1170
COELORINCHUS OCCA	2	1	751
BATHYUROCONGER VICINUS	2	2	850 - 1135
BATHYCLUPEA SP.	2	2	346 - 521
BASSOZETUS SP.	2	1	2504
ACANTHONUS ARMATUS	2	1	2504
VENTRIFOSSA MACROPOGON	1	1	521
STOMIAS AFFINIS	1	1	632
SCIADONUS PEDICELLARIS	1	1	627
SCIADONUS C.F. GALATHEA	1	1	629
SACCOGASTER STAIGER	1	1	354
RINOCTES NASUTUS	1	1	1170
RAJIDAE BIGELOVI	1	1	751
RAJA LENTIGINOSA	1	1	342
PRIONOTUS STEARNSI	1	1	329
PENOPUS SP.	1	1	1135
OPHICHTHUS CRUENTIFER	1	1	654
NEZUMIA BUBONIS	1	1	632
NEOBYTHITINAE	1	1	1064

Attachment A2.10 (cont'd).

Taxa	Abundance	Number of Stations	Depth Range
NEOBYTHITES SP.	1	1	479
NEMICHTHYIDAE	1	1	2074
MYXINE GLUTINOSA	1	1	850
MORIDAE	1	1	1064
MACRORHAMPHOSUS SCOLOPAX	1	1	329
LEPOPHIDIUM BREVIBARBE	1	1	329
HOVELLA SP.	1	1	464
HOPLUNNIS SP.	1	1	634
HILDEBRANDIA GUPPYI	1	1	351
HEPTRANCHIAS PERLO	1	1	354
HELICOLENUS DACTYLOPTERUS	1	1	366
GADOMUS SP.	1	1	871
ETMOPTERUS PUSILLUS	1	1	627
DECAPTERUS PUNCTATUS	1	1	786
CORYPHAENOIDES SP.	1	1	1135
BOROSTOMIAS ANTARCTICUS	1	1	632
BATHYPTEROIS SP.	1	1	625
BATHOPHILUS SP.	1	1	1440
APISTRURUS LAURUSSONII	1	1	1170

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